WROUGHT IRON *for* UNDERGROUND SERVICES

A TECHNICAL BULLETIN PREPARED BY THE ENGINEERING SERVICE DEPARTMENT

A. M. BYERS COMPANY • PITTSBURGH, PA.

Underground Bulletin

The illustration on the front cover of this bulletin shows a new Byers genuine wrought iron water service line in Akron, Ohio, being installed by the jacking method. Akron is one of a number of communities in the state which use wrought iron for this purpose.

WROUGHT IRON FOR UNDERGROUND SERVICES

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FOREWORD

Slowly but surely the engineering profession is becoming keenly conscious of the fact that there is no one metal or other material ideally suited for all uses. Obviously, materials vary not only in physical properties, corrosion resistance, and ease of fabrication, but also in cost. The best material is the one that will perform the required duties at the lowest annual cost.

We, as manufacturers of a variety of wrought iron, carbon steel, and alloy steel products, are not unmindful of the merits of each class of material and any attempt to prove that any one material is superior to any other, under **all** service conditions, would be contrary to good engineering. Each material excels, however, in one or more fields.

This bulletin is confined to a discussion of corrosive conditions commonly associated with underground applications and an effort has been made to select a few of the many services where the test of time has built up a fund of evidence regarding the durability of wrought iron.

A. M. BYERS COMPANY

Manufacturers of

Genuine Wrought Iron
Tubular and Hot Rolled Products
Steel Tubular Products
Alloy Steels
and
High Heat-Resisting Steels

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FACTORS INFLUENCING SOIL CORROSION

There are many phases of the soil corrosion problem and the great diversification of causes makes it one of the most difficult faced by the corrosion engineer. It is beyond the scope of this bulletin to discuss in detail such subjects as soil types, galvanic or electrolytic effects, the effect of bacterial growths, protective coatings and soil corrosion tests; but brief comments will be made on each of these topics.

One phase of the problem, however, that will be dealt with in considerable detail is the inherent corrosion resistance of wrought iron. All too often attention is directed toward factors having a minor effect on corrosion rates, while little thought is given to the very important question of material composition.

Wrought iron differs greatly from the other ferrous materials and is the only one characterized by high purity base metal and uniformly distributed fibres of glass-like silica slag. Being a different metal, it is natural that it should react differently to the corrosive action of soils.[1]

In this bulletin will be found factual data indicating that wrought iron does behave differently and that it is highly resistant to soil corrosion. The evidence submitted is highly practical; it consists of records of installations that have stood the test of time. Also, lest the present be overlooked in a study of the past, records of new installations have been included. Thus, while wrought iron's history goes back to the pyramids, it is still as modern as tomorrow, and it is unique in that its long past provides sound data on which to base estimates of probable future life under corrosive conditions.

Before proceeding with specific information on wrought iron, however, a few remarks may well be made regarding some of the general aspects of soil corrosion and its causes.

[1]It is beyond the scope of this bulletin to describe the process of manufacture of wrought iron, but this topic is covered in detail in the book "Wrought Iron, Its Manufacture, Characteristics, and Applications". Complimentary copies will be sent in response to business letterhead requests.

Soil Types

Standard works on geology classify soils as belonging to one of eight or more main soil groups, such as the gray desert soils, the yellow or red soils of the South, the brown prairie soils, and the gray-brown soils of the Middle-Atlantic states. In these main groups, there are many subdivisions, depending upon local variations. It is possible, therefore, to classify soils in a systematic manner.

Attempts to predict the corrosive action of a given soil have not, however, been very successful. It is known that, in general, the well-drained soils are less corrosive than those saturated with moisture, but it has not been possible to correlate the moisture-retaining properties of soils with their corrosive activity in such a way that quantitative predictions are possible.

Relative acidity (measured by the pH value) is not an entirely reliable index of corrosivity and neither is the electrical resistance, or a chemical analysis of the water extracted from the soil. All of these factors are useful indications of probable corrosive action, but no one or two of them tell the whole story. Moreover, a test at one location may not give results applicable to other locations nearby, and daily measurements at the same location may vary greatly depending upon sub-surface moisture variations.

Thus, while all these factors may be interesting indications, actual service experience is the best and most reliable basis for selecting materials.

Galvanic and Electrolytic Effects

Electrical phenomena have often been observed in connection with corrosion, and it is now generally accepted that corrosion is accompanied by the flow of an electrical current from the metal through the soil or water, and back to the metal. Flow of current

through the metal itself completes the circuit. Where the current leaves the metal, there is an area, called the anode, which is electrically positive to the surrounding material, and the region where current returns from the surrounding material to the metal is negative. This area is called the cathode.

Metal goes into solution at the positive or anodic areas, where the current leaves the metal, and hydrogen gas is deposited at the negative, or cathodic region.

Since hydrogen is a poor conductor of electricity, corrosion practically stops unless the film of gas is removed. Oxygen in solution does this, by reacting with the hydrogen to form water, H_2O.

At the same time, the oxygen also reacts with the freshly-dissolved iron, to form iron hydroxide, or rust. This rust film forming at the positive pole interferes with corrosion processes to an extent dependent upon its density, thickness, and intimacy of contact with the metal. Thus it is obvious that wrought iron's well-known ability to form a very dense and adherent rust film, is a valuable asset.

When the positive and negative areas are small and closely spaced, covering the entire metal area, the metal is eaten away in small closely spaced pits, and the corroded metal surface, after cleaning, is pock-marked or has a pebbly appearance.

However, since soils are composed of materials that are not homogeneous and uniform, they do not always provide conditions under which a uniform corrosion pattern can develop. Frequently, non-uniform action takes place and deep pits form at scattered locations on the metal. These pits constitute the most serious threat to pipe life, since they can cause penetration of the pipe wall long before the average wall thickness has been seriously reduced. It has frequently been observed that the slag fibres in wrought iron interfere with the deepening of these pits, and cause them to spread over the surface instead of growing deeper.

When long pipe lines pass through soils of different compositions, the positive and negative areas may be widely separated and electrical currents of considerable magnitude may flow along the pipe.

While these currents usually result from the reactions between the pipe and the soil, when external power sources, such as trolley lines or electrical grounding wires are involved, flow of current through the pipe may also be artificially produced. In either case, corrosive action occurs where the current flows from the pipe to the soil. To avoid electrolysis due to these causes, it is desirable to connect or "bond" pipe lines to trolley tracks with a heavy metal cable, or provide some other means of preventing current from flowing from the pipe to the soil.

Pipe line operators have at times deliberately applied electrical currents to their lines to keep them negative to the surrounding soil. In these "cathodic protection" systems, current always flows from the generator to grounding rods driven in the soil near the pipe, and then from the pipe through a cable back to the generator. The grounding rods are corroded by the current as it leaves them to enter the ground, but the pipe is protected.

Over-all cost for maintaining cathodic protection on bare pipe lines is sure to be excessive. For this reason, cathodic protection has thus far been limited almost entirely to the protection of coated lines in an effort to eliminate the localized corrosion often found with lines having a protective coating. Thus, while sound in principle, these cathodic protection arrangements have not been economically feasible as a means of protecting any but a limited number of large lines or systems where the power and equipment cost, and the expense of securing the services of a qualified operating expert, could be justified.

Bacterial Action

In the preceding section it has been pointed out that hydrogen is released in the corrosion process, and unless this gas is removed, corrosion is practically eliminated. Oxygen is normally required in this hydro-

gen-elimination step, but recent studies have indicated that in the absence of dissolved oxygen, certain bacteria can chemically transform sulphate salts.

In a typical soil containing calcium sulphate, the products of the reaction between the hydrogen released by corrosion, and the sulphate salt, would be hydrogen sulfide, calcium hydroxide, and water. The bacteria are necessary to cause the reaction to proceed, and the hydrogen sulfide gas is, of course, the familiar corrosion-accelerating ingredient of many crude oils, having the characteristic "decayed egg" odor. It reacts with iron to form iron sulfide.

In the section of this bulletin devoted to oil and gas wells, data on the resistance of galvanized wrought iron tubing to hydrogen sulfide corrosion will be found. Thus, while investigations of bacterial corrosion are still in their early stages, there is reason to believe that wrought iron may have merit in overcoming its effects.

Protective Coatings

Protective coatings fall into two main groups; namely, the metallic and non-metallic types. Hot-dip galvanizing, applied by immersing the cleaned pipe in a bath of molten zinc, is the most popular of the metallic coatings. For a wide variety of corrosive services the economic justification for its use is well established.[2]

The non-metallic coatings are infinite in variety, ranging from heavy cement coatings reenforced with mesh, to simple paints. Many are of a bituminous nature and may or may not be applied in conjunction with fibrous wrappers of various types.[3]

In thinking of all coatings, it must be kept in mind that they are an applied, as opposed to a built-in, opponent of corrosion. In wrought iron, corrosion resistance is a characteristic of the metal and cannot be made inoperative by superficial damage. If the protective rust film that forms on wrought iron is damaged, a new layer forms. It is self-healing.

An applied coating, on the other hand, cannot repair itself; it must be designed to remain 100% intact under all operating and installation conditions. A coating that is 99% effective, but leaves 1% of the surface exposed, permits penetration of the pipe wall to occur in no more time than would be the case if no coating at all were used. In fact, coatings often cause galvanic action due to concentration cells forming at small breaks in the insulating layer, and so may even hasten the time of failure. Thus, a coating must first, last, and always, remain continuous and unbroken if it is to be effective.

In practice, it is extremely difficult to install a line of coated pipe and still have the coating intact. Mill-applied coatings are often damaged in transit, particularly if several handlings are necessary. This requires field patching as well as coating of the joints, and in the field, adverse conditions often make it impossible to do a first-class coating job.

When the whole line must be coated in the field, the problem is even more difficult, since it is a practical impossibility to keep pipe clean and dry in any but perfect weather. A coating applied to a wet or dirty surface will be loosened from the metal and become inoperative by rusting of the metal underneath the coating.

If, in spite of these installation hazards, the coating is intact when placed in the trench, to remain so it must resist damage by soil action. Many fibrous wrappers decay when buried. Other coatings permit moisture to penetrate to the pipe surface, rusting occurs, and as the rust builds up the coating is loosened and becomes ineffective. Hard coatings are easily chipped by rocks and may be subject to cracking or drying-out of the binder compound. Soft coatings, if thin, are easily punctured by rock pressure and, on many occasions, thick, soft coatings have been damaged by soil shrinkage. Rocks and clods adhere to the coating, and when the

[2]For supplementary information on galvanizing, write to the Engineering Service Department, A. M. Byers Company, Pittsburgh, Pa.

[3]A publication dealing in more detail with the subject of non-metallic pipe coatings is available on request.

soil moves, the coating is pulled away from the pipe.

The foregoing should not be interpreted as meaning that it is impossible to design a satisfactory coating for each type of exposure, provided cost is no consideration. It has been our experience, however, that many coatings which apparently had great merit, have failed to stand up in service, and have proven more costly in the end than a corrosion-resisting metal without any coating. It is only when corrosive conditions are so severe that the available piping materials are not suitable, that coatings need be used, and when used, they should be made adequate to give complete protection. Attempts to use compromise coatings with materials lacking in corrosion-resistance have, we have observed, merely ended in failure of both the coating and the pipe, and several such instances are mentioned in this bulletin.

Soil Corrosion Tests

Soil corrosion tests are made in order to develop reliable information on the rate of corrosion of metals in typical soils. Their chief use is in predicting the life of pipe or other material buried in soil, and in indicating when special installation procedures are necessary.

Obviously, if test results are reliable as a basis for new designs, they should check past experience equally well. If they do not agree with records of actual installations, then they are not worth much to the designer. In a word, test results should be checked against experience records before they are used.

It is difficult to plan a test so that some variables do not render the results useless, and it is very easy to overlook the importance of seemingly minor considerations. For example, it might seem that tests on small samples of pipe buried in soil would give results typical of those which would be obtained by testing long lines of pipe buried in the same soil. On this assumption, the National Bureau of Standards, collaborating with various pipe line companies, buried about 33,000 samples of various types of pipe from 6" to 12" long in soils typical of those found in all parts of the country. After seventeen years, during which a great mass of data was collected and tabulated, Research Paper RP 1171 was published in the Journal of Research of the National Bureau of Standards. It was entitled "Engineering Significance of National Bureau of Standards Soil Corrosion Data", and on pages 122 and 123 some comments are made on Soil #32, Ontario Loam. The following quotations are abstracted from these comments:

> "The test site lies within a few feet of a 38-inch steel water main having a 5/8-inch wall. Within 2,000 feet of the test site this line developed 25 leaks in 42 years. The line was protected by a japan varnish baked on . . . The Bureau's data show that in this case the soil is much less corrosive than experience proved it to be. However, the steel main is paralleled by a 36-inch wrought iron main having a 3/8" wall which has developed no leaks in this soil in 61 years . . . The record of these pipe lines illustrates very well how conditions not duplicated in a test may alter the results when the material tested is used in a practical way."

Similar trouble was found in correlating test results in other locations with local experience data.[4]

Correlating of test results with service records is difficult because certain important factors are operative in service but are not present in tests of small samples.

Physical stresses comprise the first of these variables. Shifting soil and temperature changes stress the metal and it is well known that stressed metal corrodes more rapidly than metal to which no forces are applied. Obviously, a small sample is free from such physical forces.

Soils are not homogeneous and a pipe line must therefore pass through areas where soil

[4] We have followed the soil corrosion test program of the Bureau of Standards since its inception, and while space limitations prevent the inclusion of more data concerning the test program, additional data is available on request.

textures vary. Electrical effects may be induced under these conditions, whereas small specimens are exposed to only one variety of soil.

It has also been recognized by the Bureau of Standards investigators that by the law of averages, maximum pit depth cannot often be expected in a small sample. In other words, the deepest pit on a long line will be deeper than the average by a considerable margin. In general, wrought iron showed less pitting in the tests but its margin of superiority in this respect was less than could be expected in a full-scale installation.

While other differences might also be discussed, those mentioned may serve to indicate the hazards involved in blindly applying test results before checking them against actual operating experience.

With accelerated laboratory tests to determine rates of soil corrosion, reliable data are obviously more difficult to obtain, and it is doubtful if such tests are of much value. Chemical tests are chiefly useful in classifying soils so that experience data in one location may be applied to problems in areas where soil conditions are similar. They may also indicate the presence of unsuspected contaminating materials, such as chemical wastes, or cinders.[5]

[5]While cinders are extremely corrosive, it is possible to install pipe in cinder fills so that satisfactory service will be obtained. A leaflet is available, outlining recommended installation practices.

MISCELLANEOUS WATER LINES

Today, as in past years, large tonnages of genuine wrought iron pipe are being used for underground water lines. They range in size from small service lines up to 48" O.D. mains fabricated from wrought iron plates, such as were recently used at a new bomber plant in the southwest.[6] In this bulletin only a very few of the more recent water line installations are mentioned, but a number of service records have been included. They show conclusively that wrought iron is a durable, corrosion-resisting material, extremely well suited for underground water lines of all sizes. With records such as these, going back half a century or longer, there can be no doubt regarding wrought iron's resistance to the action of typical soils in all parts of the country.

In Pittsburgh, Pa., a 50" wrought iron water main is still in service after over 60 years use. It carries water from Brilliant Pumping Station to Highland Park Reservoir No. 2, a distance of about six tenths of a mile. Only one leak has been reported and while various records place the age of the line as between 60 and 79 years, it is still operating under about 135 pounds pressure.

[6]For a complete listing of standard tubular and hot rolled wrought iron products, write for a complimentary copy of Byers General Catalog.

When the Brilliant Pumping Station was connected to this line, it was necessary to remove the section of pipe shown in Figure 1. Analysis of the metal revealed that it was genuine wrought iron of normal quality and the surface of the pipe was in excellent condition.

Fig. 1

When it was found that steel pipe was failing in Louisiana marsh lands in as little time as four years, the Chief Engineer of the New Orleans Lake Shore Land Company mentioned that a 21-year-old 3" wrought iron main was still in service close to the shore of Lake Pontchartrain near the Shushan Airport.

This main was laid at a depth of from 12 to 30 inches and had no protective coating. It was approximately 6 miles long, and during the 21 years it had been in use, no repairs due to corrosion had been necessary. The pipe passed through three types of soil: Sharkey clay, swamp soil, and muck. All three were saturated with water most of the time.

When the line was 23 years old, it was sold in the ground to the Southern Scrap Materials Company. Upon removing it from the ground, they found the pipe in excellent condition with even the Byers name visible. After cleaning, the pipe was sold for re-use.

In San Francisco, a great deal of riveted wrought iron pipe has been used for water mains. A considerable quantity of this pipe is still in use after a half century or more of service.

For example, in Figure 2 workmen are shown removing a 200 ft. section of 44" O.D. $\frac{1}{4}$" wall genuine wrought iron pipe. It had been in continuous service for 54 years and no holes or thin spots could be found in it. Accordingly it was cleaned and placed in stock for making replacements or extensions.

The pipe used to replace the 54 year old material was also wrought iron that had served between 30 and 40 years before removal for cleaning. Part of it is shown in Figure 3.

Another old line was recently moved to make way for the Metropolitan Life Insurance Company Building Program on the Inglewood Golf Course in West San Francisco. About 1340 ft. of 22" pipe with $\frac{1}{8}$" wall thickness, and 5430 ft. of 23"—$\frac{3}{16}$" wall wrought iron pipe were removed. Figure 4 shows the work in progress.

Fig. 3

Fig. 2

Fig. 4

During the 1906 earthquake, San Francisco's only water supply was obtained through this pipe, from Lake Merced. When removed, every foot of the old pipe was examined and found to be in excellent condition.

At Fairmont, West Virginia, two lines of wrought iron pipe are used for water mains under rivers. Both are 12'' pipe and one has been in service under the Monongahela River for about 20 years. The other, about 16 years old, lies under the Tygart River. To date there has been no trouble whatsoever with either line. Figure 5 shows one of the Van Stone joints used in these lines being fabricated.

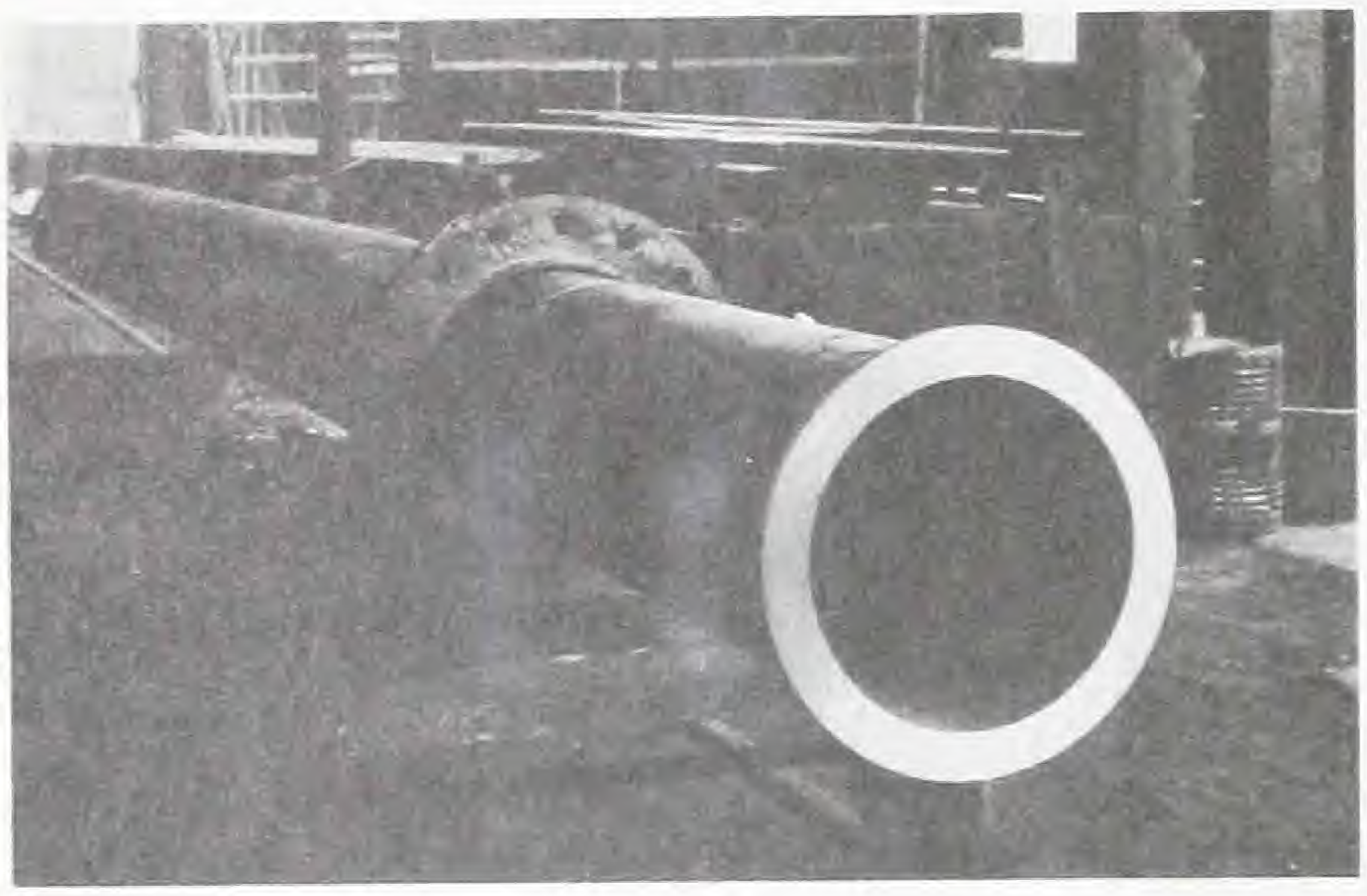

Fig. 5

In the late 1870's silver was discovered in the mountains near the present location of Tombstone, Arizona, and a boom-town immediately sprang up. By 1881 the need for a reliable water supply was so urgent that 25 miles of 7'' genuine wrought iron pipe weighing 26 pounds per foot and slightly less than four miles of 5'' genuine wrought iron pipe were shipped from Pittsburgh around Cape Horn to San Francisco, forwarded by rail to Benson, California, and then hauled by ox cart for distances ranging from 22 to 56 miles. The pipe was installed to carry water from mountain sources to the town of fifteen thousand inhabitants.

A few years ago an evaluation was made of the Water Company's properties and the water company and the utilities commission agreed that 13% depreciation in the value of the pipe was a fair estimate.

The present population of the town is about four hundred and recently some alterations were made. We were able to obtain a sample of the original 7'' pipe, and chemical analysis revealed that the material was quite comparable to that produced today. The sample, typical of the rest of the pipe, was still in excellent condition.

Condenser cooling water for the Central Maine Power Company's plant flows through the penstock shown, during the process of installation, in Figure 6. This pipe is of welded construction and was fabricated from 3/8'' Byers wrought iron plates. The penstock is 239' long. Several sections, ready for installation, are shown in Figure 7.

Figure 8 shows a new wrought iron penstock over 200 feet long and 52'' in diameter being installed at the American Felt Company's plant in Glenville, Connecticut. Five-sixteenth inch plates were used by Walsh Holyoke Steam Boiler Company of Holyoke, Massachusetts, in fabricating this pipe and, as can be seen in the photograph, the pipe is laid inside the old wooden penstock which was being replaced. Due to seepage of ground moisture through the old penstock, and the possibility of tannic acid being leached from the wood, highly corrosive conditions can be expected and for this reason, wrought iron was selected.

Most of the water lines around a typical swimming pool are buried directly in the soil, and the corrosive nature of water which is saturated with air also makes it desirable to use corrosion-resisting piping. Frequently, the chemicals used to purify the water accelerate corrosion. For these reasons, many pools are piped with wrought iron.[7]

A typical installation is shown in Figure 9. This view was taken at the North Park Pool, near Pittsburgh, Pennsylvania. Wrought iron pipe up to 16'' diameter was used for this project, which is one of the largest in the eastern part of the country, holding 2,500,000 gallons of water. It is 360 feet long and 164 feet wide.

[7]A separate publication dealing exclusively with swimming pools is available.

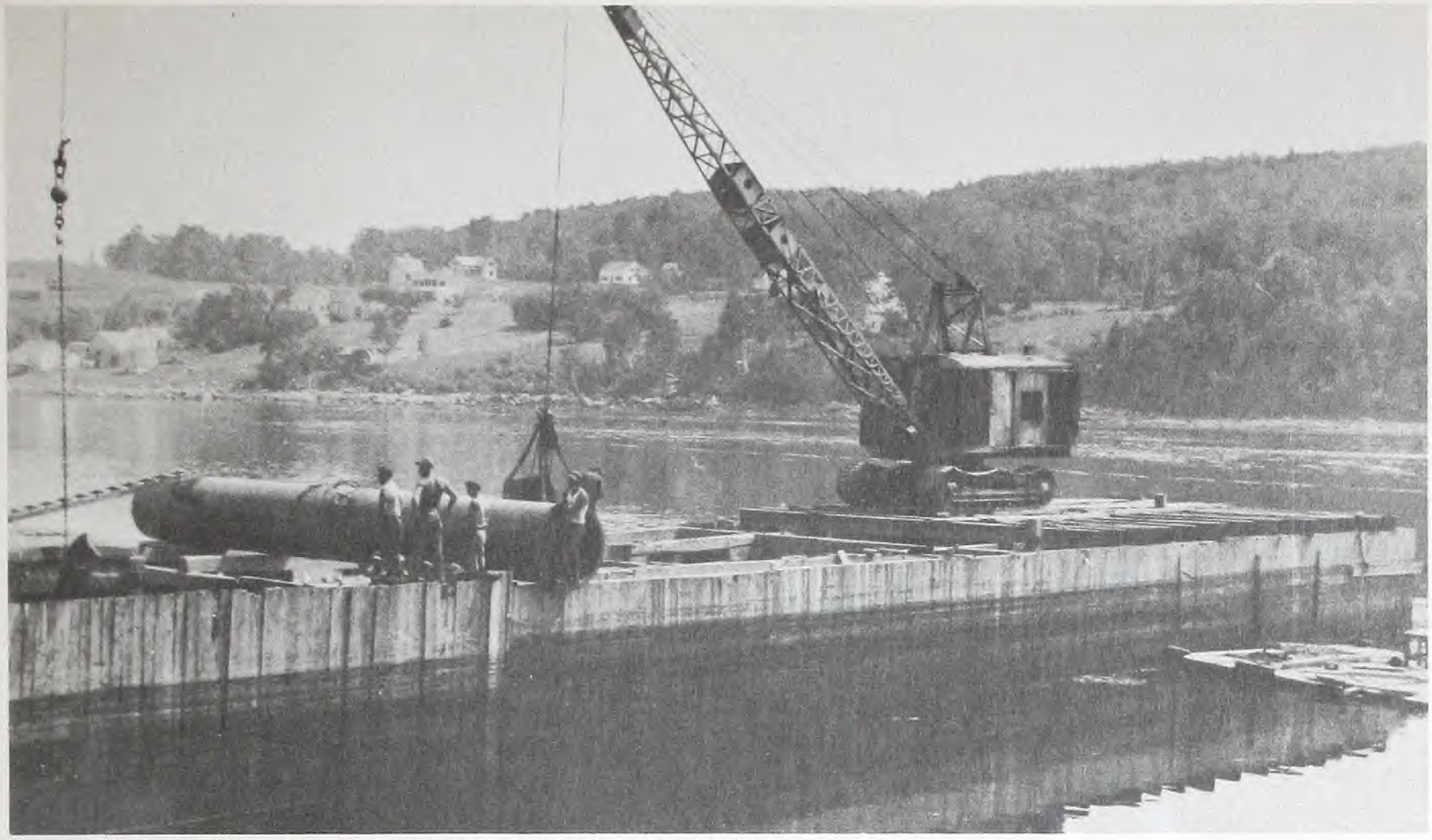

Fig. 6

Fig. 7

Fig. 8

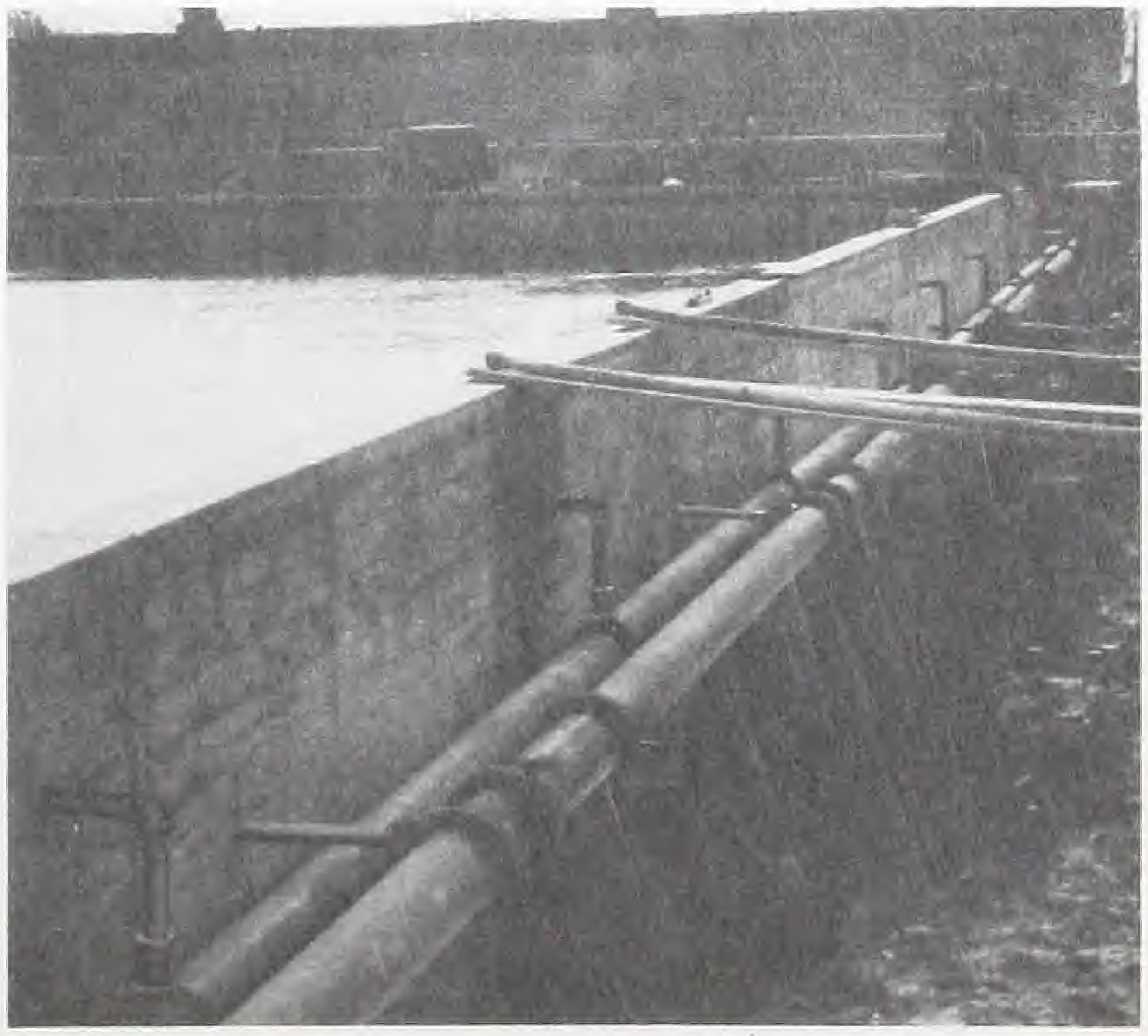

Fig. 9

WATER SERVICE LINES

The pipe connecting a building's piping system to the main or other source of supply is a very important line, but in writing a building specification it is easy to overlook it and thus allow the installation of material lacking in the durability needed for continuous trouble-free service. Probably no line in the building will, however, cause as great inconvenience as a result of failure or be more difficult to replace.

In many municipalities, wrought iron is the accepted material for service lines, and of the communities which have purchased wrought iron for this application, the following few may be considered typical: Newark and Atlantic City, New Jersey; Baltimore, Maryland; Charlotte and Raleigh, North Carolina; Chicago, Illinois; Evansville, Indiana; Hartford, Connecticut; Pittsburgh, Pennsylvania; Spokane and Seattle, Washington; Springfield, Missouri; and New Orleans, Louisiana.

Fig. 10

We have been informed by the Superintendent of Water Supply of the City of Charlotte, North Carolina, that wrought iron is the only material in use there for water service lines ½" to 3" in diameter. Figure 10 shows a new 2½" galvanized wrought iron service line being installed to serve a land development along Wilkenson Boulevard. The pipe was jacked under the four-lane roadway.

For years, water superintendents in Statesville, North Carolina and Greensboro, North Carolina, have also been using wrought iron for service lines.

Engineers in Pittsburgh all agree that the water supply is corrosive. After thirty-five years service it was necessary to replace an underground water service line supplying a row of houses on Kelly Street in the Homewood District of Pittsburgh. A sample of this two inch line was obtained and found to be of composition quite in harmony with present standards for high quality genuine wrought iron.

An interesting record of a water service line which is still giving service after 45 years use, was recently obtained from the General Superintendent of the New Haven Water Company. This ¾" galvanized wrought iron line is about 500 feet long and is buried in sandy soil. Entirely trouble-free service has been rendered by it.

Through the courtesy of Mr. H. W. Hanscom, Consulting Engineer, of San Francisco, we had an opportunity to examine several pieces cut from an old ¾" water service line. The material proved to be galvanized wrought iron of normal quality. The following quotation is from the letter from Mr. Hanscom:

"A short while ago we had occasion to replace an underground water pipe service that had been in wet soil for 35 years. It had not failed but other pipe in the neigh-

borhood had, so it was considered advisable to make the change while other work was going on.

"The inside was in perfect condition as was that portion of the pipe projecting above the ground. The part underground had rusted all over the exterior surface, quite evenly, but was about ready to go at the threads although the rest of the wall was practically of its original thickness."

Many wrought iron water service lines have given 43 years service in Olwein, Iowa and it is our understanding that in this community, ¾" extra-heavy wrought iron pipe is being used at the present time for water service lines. Some years ago steel was tried, but it lasted only about 14 years under conditions identical to those to which the wrought iron was exposed.

An underground water line was recently removed from an estate near Stockbridge, Massachusetts and we were interested to learn that it had been in continuous service for about 70 years. The material was 1" pipe and an analysis of two samples and a coupling revealed that the material was genuine wrought iron.

Figure 11 illustrates the excellent state of preservation of the samples forwarded to us for examination.

Fig. 11

LAWN SPRINKLING PIPING

The sprinkling systems serving golf courses, cemeteries and extensive lawns or gardens require considerable quantities of pipe, and it is poor economy to use a piping material which may require replacement in a few years. Wrought iron has often been used for these lines, and the service life obtained has been excellent.

At Prairie Home Cemetery, Waukesha, Wisconsin, the original sprinkling system piping was genuine wrought iron and for 43 years it gave entirely satisfactory service. When additional capacity was needed it was logical for the superintendent to select genuine wrought iron for the new piping. Figure 12 shows the new piping being installed. The old pipe, when removed, was found to be in such good condition that it was used again for other parts of the system where smaller lines were needed.

Fig. 12

Wrought Iron sprinkler system piping was installed in the lawn of the Nebraska State Capitol in Lincoln, Nebraska, and recently, after 11 years service, the building custodian informed us that the sprinkling system "has proven entirely satisfactory".

Wrought iron pipe was selected for the sprinkling system for the City of Boston Municipal 18-hole Golf Course at Hyde Park about eleven years ago and a recent conversation with the park superintendent revealed that there has been absolutely no trouble with the pipe. It is our understanding that for extensions to the system wrought iron has also been selected.

At the Western Regional Research Laboratory of the U. S. Department of Agriculture, Albany, California, a lawn sprinkling system was recently installed, using wrought iron pipe. Figure 13 shows the system in operation.

Fig. 13

Figure 14 shows wrought iron pipe ranging in size from ½" to 3½" being installed in the lawn of the Wyoming State Capitol at Cheyenne, Wyoming. This lawn covers two city blocks and the pipe supplies water to 450 sprinkler heads.

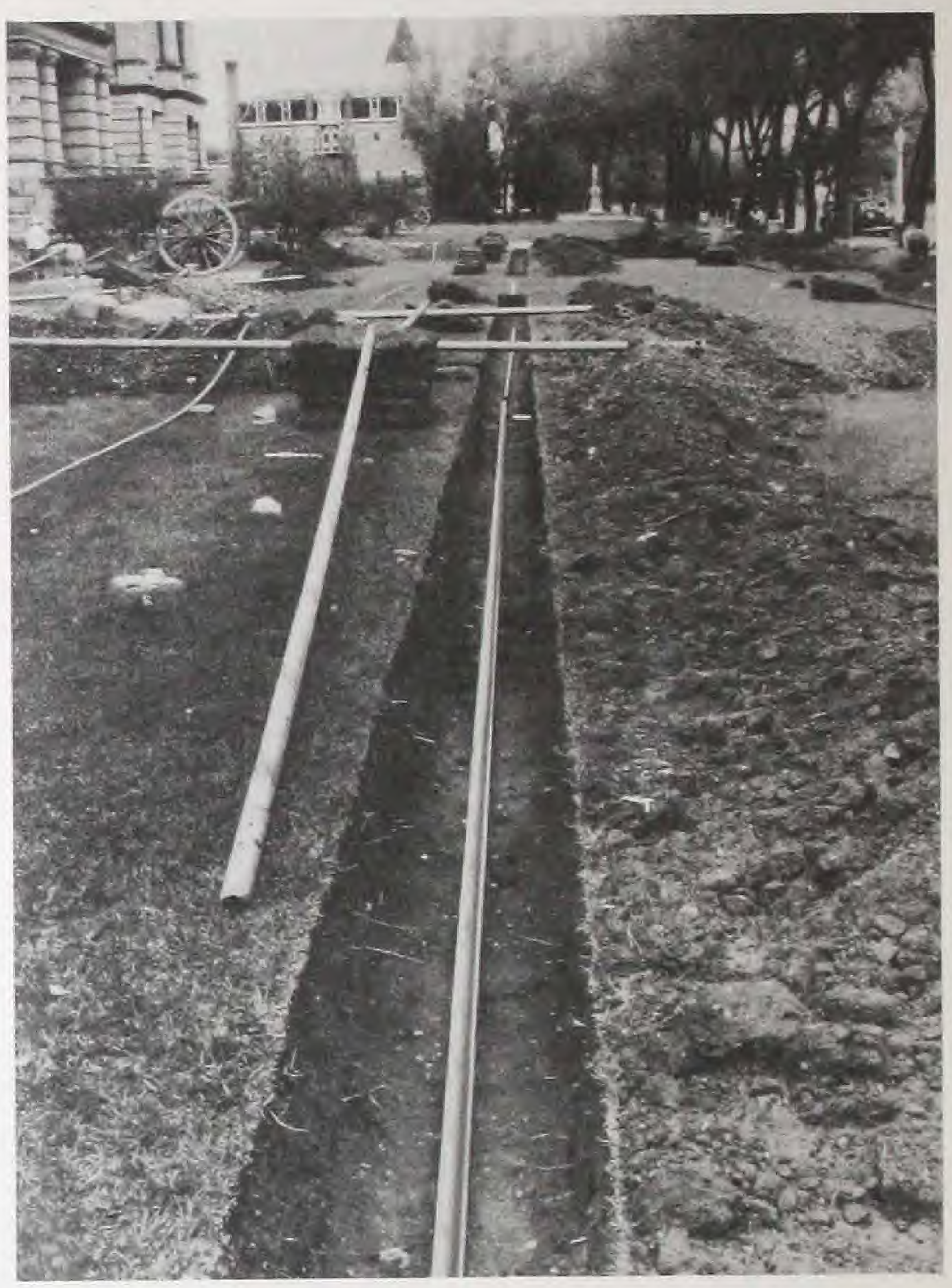

Fig. 14

WATER WELLS

Corrosion-resistance is particularly important in water well casing, because of the health hazard incidental to failures. It is to be expected that water from deep strata will be relatively free from bacteria, but dangerous surface water contamination can easily result from leaks in the casing. For this reason, many authorities consider it wise to standardize on wrought iron.

Along the sea coast, salt water contamination may also be troublesome if casing leaks occur.[8] As service records cited in this bulletin show, wrought iron can be depended upon to give long service as well casing, and it is now being used in many hundreds of installations.[9]

At Knoxville, Illinois, the casing of an old water well was finally replaced after 40 years' service. The well was recased with 1056 feet of 6¼"—20 lb. wrought iron California XL Casing.

At the same time, another new well was drilled to a depth of 2498 feet, and 8¼"—28 lb. and 6¼"—20 lb. wrought iron casing

[8]For more detailed information on the resistance of wrought iron to salt water corrosion, write for a copy of "Wrought Iron in Salt Water Services."

[9]A supplementary publication, dealing only with the use of wrought iron for water wells, is available on request.

were used. Fig. 15 shows casing being installed in this well.

An unusual artesian well installation supplies water to the Hull Brewing Company in New Haven, Connecticut. The flow from twenty-two wells is gathered into headers, one of which is shown in Figure 16. The individual wells consist of 2½" black wrought iron pipe, with a screen at the bottom of each well, and all the connecting pipe is also wrought iron.

In Detroit, Michigan, one of the leading salt producers used wrought iron tubing and casing in a salt well, replacing steel that had failed as a result of corrosion, in 1½ years. The air lift method is used in this well, and mixing air with brine creates, of course, severe corrosive conditions.

After the wrought iron had been in service two years, the casing and tubing were pulled and inspected. Corrosion had had so little effect on the wrought iron that it was all run back into the well.

At the plant of a large machinery manufacturer in Cincinnati, Ohio, there are three wells, all cased with Byers 10"—41 lb. line pipe. They are about 230 feet deep, and are driven to bed rock. An investigation when these wells were 23, 20, and 14 years old, respectively, revealed that no trouble had been experienced.

Pure water is an essential raw material in the manufacture of all beverages, and to minimize interruptions of their supply, Joseph E. Seagram and Sons recently cased two new water wells at their Louisville, Kentucky, distillery with wrought iron. These wells were slightly over 100 feet deep, and 16" casing was used.

Figure 17 shows Byers 10"—32.75 lb. black wrought iron casing being run into a deep well at the Houston, Texas, Roundhouse of the Houston Belt and Terminal Railway Company. Approximately 25 tons of casing were required for this well.

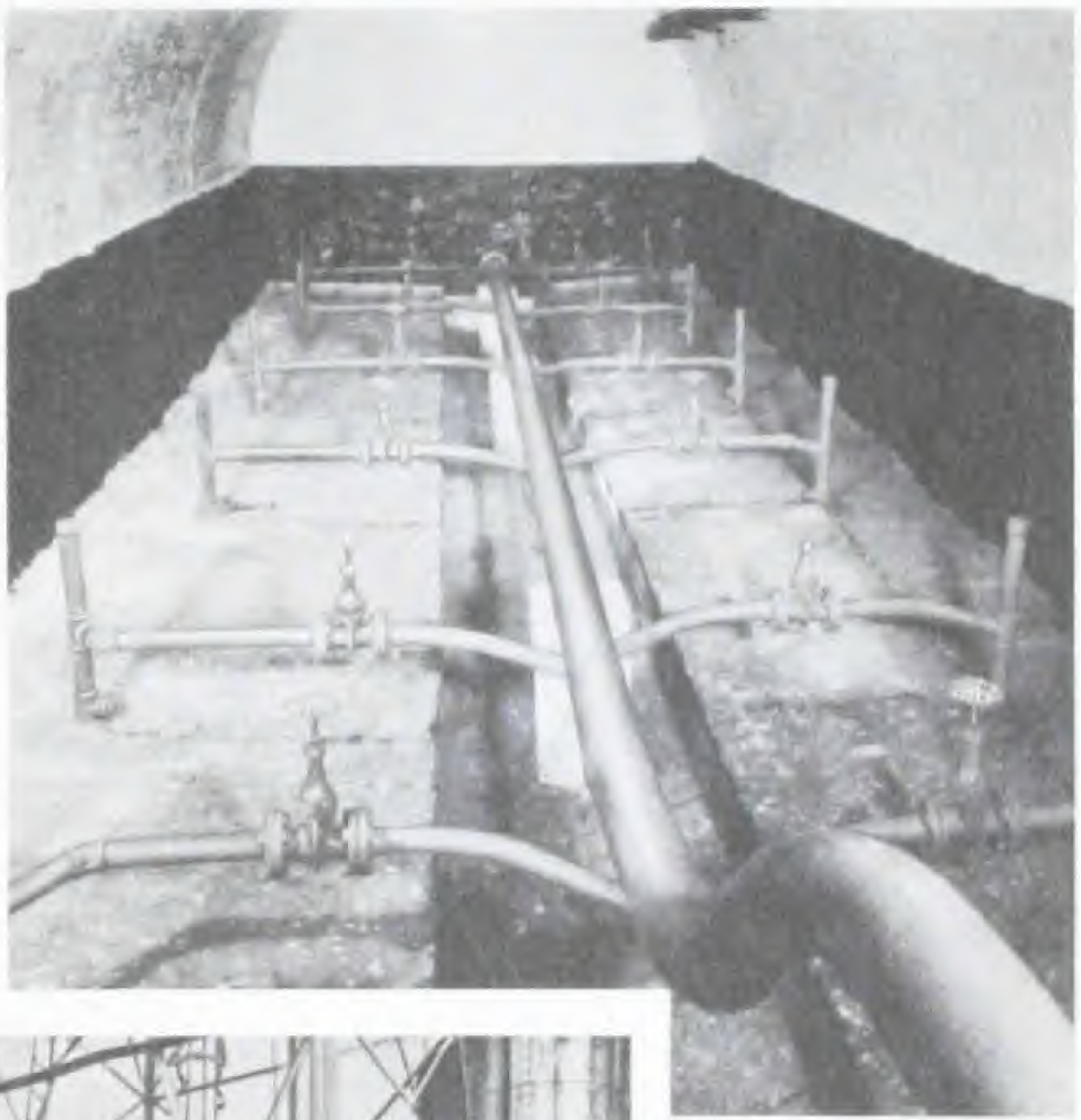

Fig. 16

Fig. 15

Fig. 17

At Marysville, Ohio, Nestle's Food Corporation replaced steel casing in a water well several times, and each time the new casing failed after only two years. Finally they used 6" wrought iron for the casing, and in the succeeding 10 years they had no further casing failures.

Along the New Jersey and Delaware Coast, many communities depend upon wells for their water supply. Since the soil is usually saturated with salt water from a few feet under the surface down to a considerable depth, it is essential that the casing be perfectly tight or salt water contamination will result. The salt water creates very severe corrosive conditions, and in many localities oyster shells in the soil further aggravate corrosion by introducing sulfur and organic compounds. Still, wrought iron has given very satisfactory service.

For example, a service life of 25 years for well casing has been reported at Ventnor, N. J., and no failures have been recorded at Beach Haven, N. J., where there are five wells, all cased with wrought iron. The first of the five is now over 40 years old, and all five pass through sand and highly corrosive salt mud. The original wrought iron casing in the oldest of six wells at Seaside Park, N. J., has given over 40 years' service, and the other five are also cased with wrought iron. At Lewes, Delaware, similar service life has been recorded, and here the water is very corrosive due to its high carbon dioxide content.

Mr. A. C. Gray, President of Gray Well and Pump Corp. in Jacksonville, Florida, recently mentioned a few of the wells in which they have installed wrought iron casing. They included wells at Jacksonville, Florida, where wrought iron casing is a standard specification, at Lake City, Florida, and at the Prison Farm at Tallahassee, Florida. Mention might also be made of wells at Nichols, Ludowici, Newton, and Lumber City, Georgia, and at the State Prison Farm at Riedsville, Georgia.

Water resources on Long Island are limited and government regulations require that if well water is to be used for air conditioning condenser cooling purposes that it either be recirculated or returned to the ground after use. Thus it was necessary for Arnold Constable & Company to drill two wells when they installed an air conditioning system in their new store in Hempstead, Long Island. Eight-inch wrought iron casing was installed in both wells and 4" wrought iron was selected for drop pipe, in the supply well. Water is drawn from this well, passed through the condensers and returned to the same sand strata through the second well.

At Rockford, Illinois a 10" well, cased with wrought iron, was deepened and enlarged to 18" diameter in order to obtain increased capacity. The old casing had been in service 52 years and when removed was still in good condition. Fig. 18 shows some of it just as it came out of the well. It was in such good condition that it was reinstalled in another well. Wrought Iron was, of course, used for the new well casing.

Fig. 18

Sixteen-inch O.D. $\frac{3}{8}$" wall wrought iron casing was used for a well at the S. Davis Wilson Airport in Philadelphia and Fig. 19 shows a length ready for lowering into the well. Plain-end pipe with a collar welded on one end of each length was used. As each section was lowered into the well with the collar end up, the next length was inserted in the collar and welded. The collars thus provided a means of holding the string while the next length was being welded in place.

Wrought Iron drive pipe was used for an interesting group of six wells at Ambridge, Pa., a few miles down the Ohio River from Pittsburgh. The wells were only 35 to 40 feet deep so that two random lengths of 12" 51 lb. drive pipe were sufficient for each well. A pointed shoe was screwed on the end of the pipe and slots were cut in the end of the bottom length of each pipe to serve as a strainer. Figure 20 shows the slotted pipe prior to installation and Figure 21 is a close-up showing the pipe being driven into the earth. For work of this type the pipe is threaded so that the ends butt together in the coupling. This enables the force to be exerted on the ends of the pipe rather than on the threads.

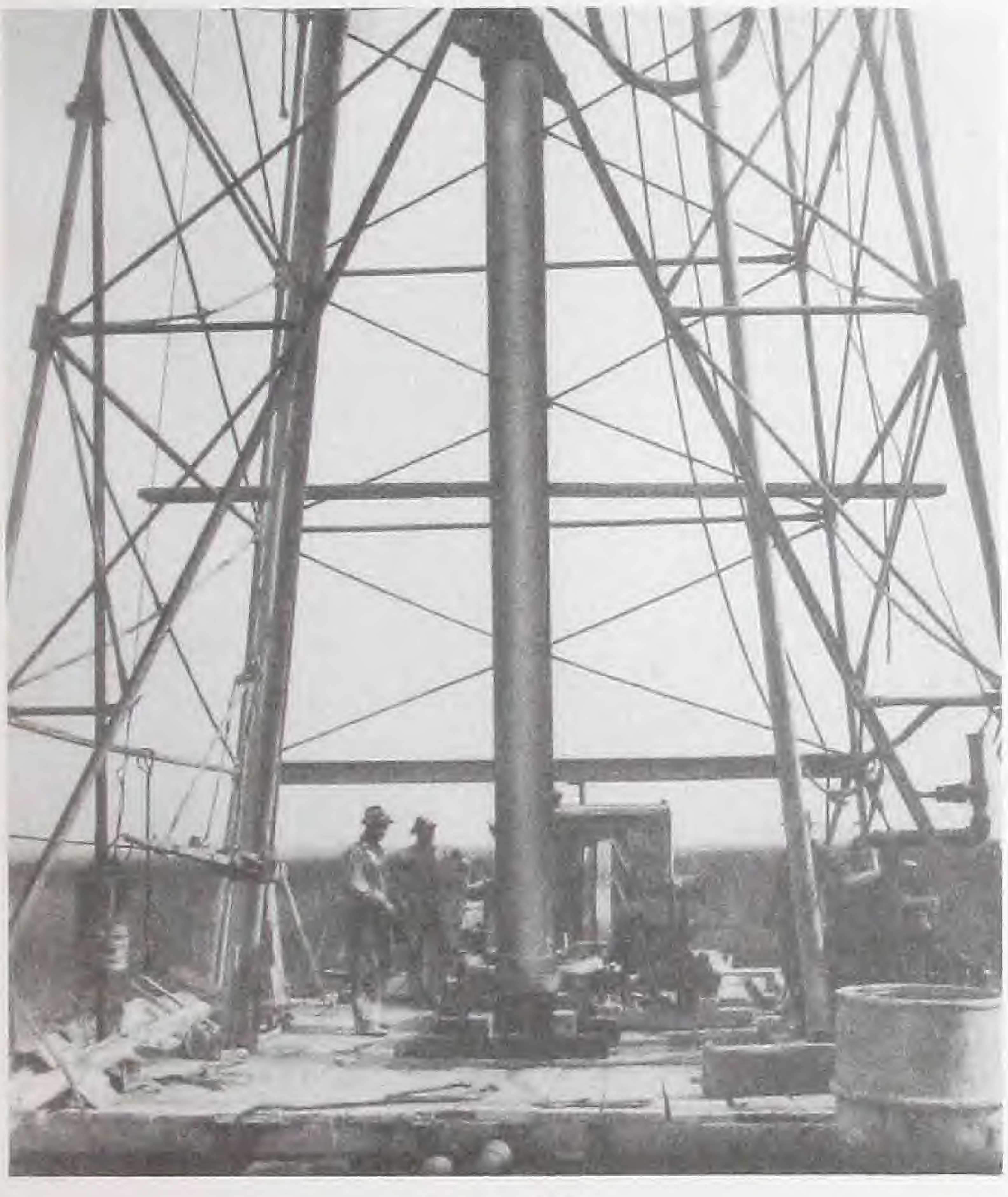

Fig. 19

Fig. 20

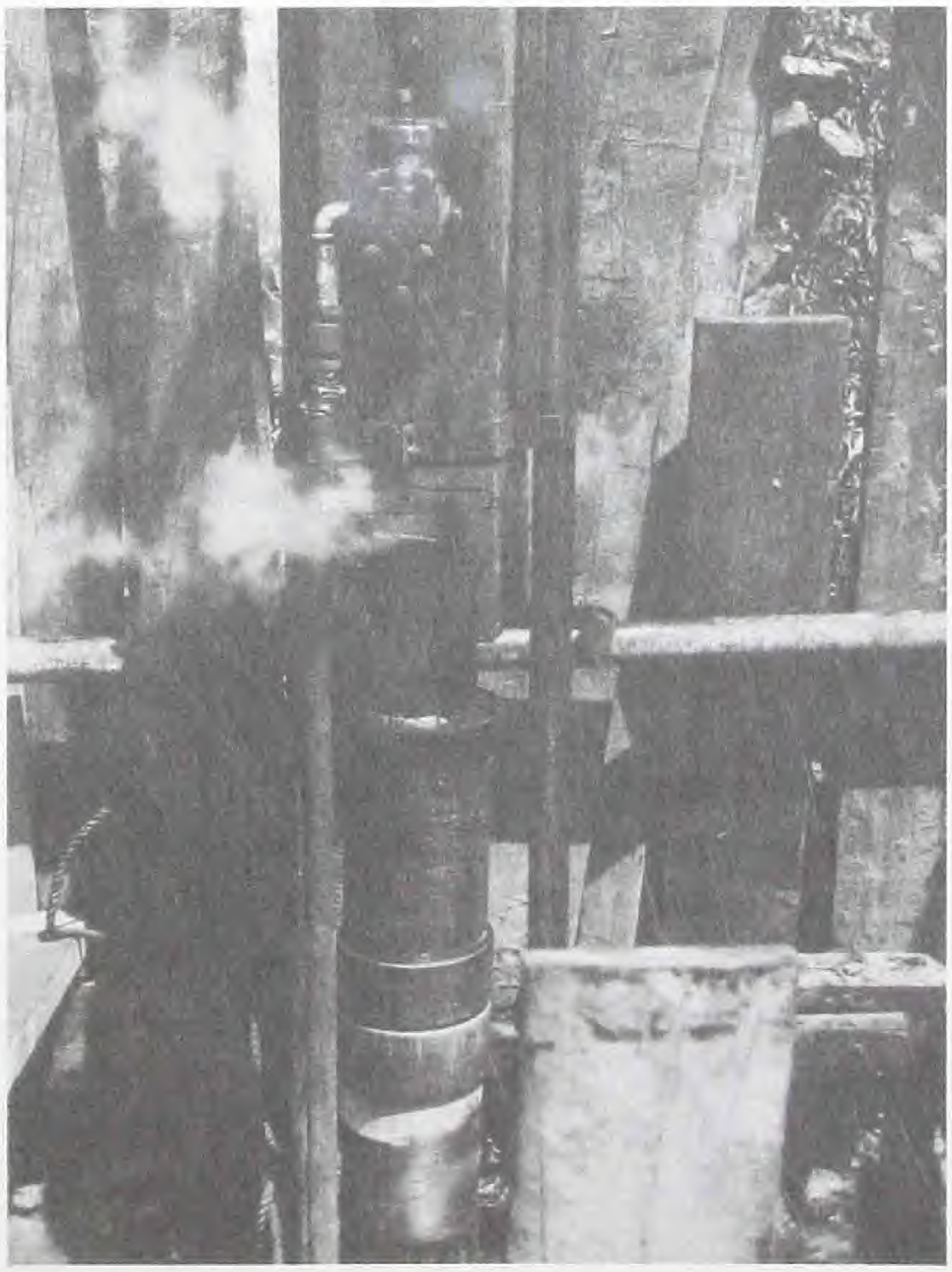

Fig. 21

OIL AND GAS WELLS

In many oil and gas fields, replacement of equipment destroyed by corrosion is a major item in the cost of production of crude oil or gas. Salt water and hydrogen sulfide are the most troublesome corrosion accelerators.

When sour crude must be handled, it is suggested that producers investigate the suitability of black or, preferably, galvanized wrought iron tubing.[10] In a considerable number of wells, the added life obtained has more than offset the additional first cost.

Fatigue is also a factor in determining the service life of tubing, since the stresses applied in service are cyclical. The experience of railroads, as well as oil producers, indicates that wrought iron is highly resistant to corrosion fatigue, and is relatively insensitive to damage due to overstressing.

In this connection, an abstract from a paper written by Mr. W. St. M. E. Crake, of the Shell Petroleum Corporation, Houston, Texas, may be of interest. The paper, entitled "Corrosion—Its Nature and Effect on Selection and Installation of Production Equipment", was presented at the Spring meeting of the Southwestern District of the A.P.I. Division of Production, San Antonio, Texas, April, 1935. Mr. Crake stated that "Corrosion of tubing is usually electrolytic, and, where severe cases of this are experienced, the use of galvanized tubing is usually profitable. Due to the better galvanizing qualities of wrought iron and the fact that tubing is under heavy cyclic loading on pumping wells, this type of tubing has proved advantageous."

A number of other men have reached similar conclusions, and some field data obtained in various parts of the country has been assembled here as an indication of typical operating experience.

In the West Texas oil fields some interesting comparative service record data has been compiled by one of the large producing companies. In one well hydrogen sulfide corrosion was encountered, and 3100 feet of upset seamless steel tubing was installed when the well was first put on pump. Corrosive action was so severe that it was necessary to replace the entire string of tubing after only 213 days' service.

An identical string of upset black wrought iron tubing was then installed, and the first failure occurred after 1860 days' service.

In another well in the same field, the first string of tubing was also black seamless steel. It lasted 107 days before complete replacement was necessary, as a result of hydrogen sulfide corrosion. It was replaced with upset black wrought iron tubing which lasted 234 days before the first failure and had only 22 failures in 1600 days.

In an effort to determine the comparative life of wrought iron and steel tubing, a very extensive series of records was kept by one of the producers in the Gulf Coast area. One hundred forty-four strings of wrought iron tubing were studied, and the average ratio of wrought iron life to steel life was 2.12 to 1. A report was carefully compiled by the company's own engineers, and a net saving of over $200,000 was indicated as having actually resulted from the substitution

Fig. 22

[10]Technical data on permissible lengths of string and bursting strengths of various sizes of wrought iron tubing and casing will be gladly furnished on request.

of wrought iron for steel in the wells where the tests were made. Fig. 22 shows wrought iron tubing being installed in one of this company's wells.

In the oil fields near Eldorado, Kansas, salt water corrosion has been troublesome for some years, and in one well records indicated that steel tubing lasted only 30 to 60 days. Galvanized wrought iron tubing was tried for the lower portion of the tubing string, and it lasted 157 days. It was replaced with more galvanized wrought iron, and at the end of 109 days no trouble had occurred. A ratio of service life of between 2 and 3 to one was thus indicated for the galvanized wrought iron as compared to the steel. Figure 23 shows the well-distributed corrosive action typical of that which formed on the wrought iron. The steel tubing which was replaced by the wrought iron was perforated by many pits, and the complete absence of pits in the wrought iron sample was noteworthy.

Another company in the Eldorado area had similar trouble due to salt water, and in one well steel perforated at the end of eight months and in 20½ months eleven failures occurred, all near the bottom of the well. A 600 ft. test string of 2" black wrought iron tubing in the bottom of the same well lasted 13 months before the first failure, and in 24 months only one additional failure occurred.

The wrought iron had originally cost \$30.00 more than the steel, and the producing company's records indicate that it costs, on the average, \$25.00 to repair a tubing corrosion failure in that district, not counting the loss of production. On this basis, steel failures cost the company eleven times \$25.00 or \$275.00 in 20½ months. In 24 months wrought iron cost only \$50.00 for repairs, plus \$30.00 excess original cost. The net saving to the company was thus \$275.00 less \$80.00 or \$195.00. If the steel failures are prorated to put both materials on a 24 month basis, the saving by the use of wrought iron is \$245.00.

Figure 24 shows black wrought iron tubing ready to be run into another of the same company's wells.

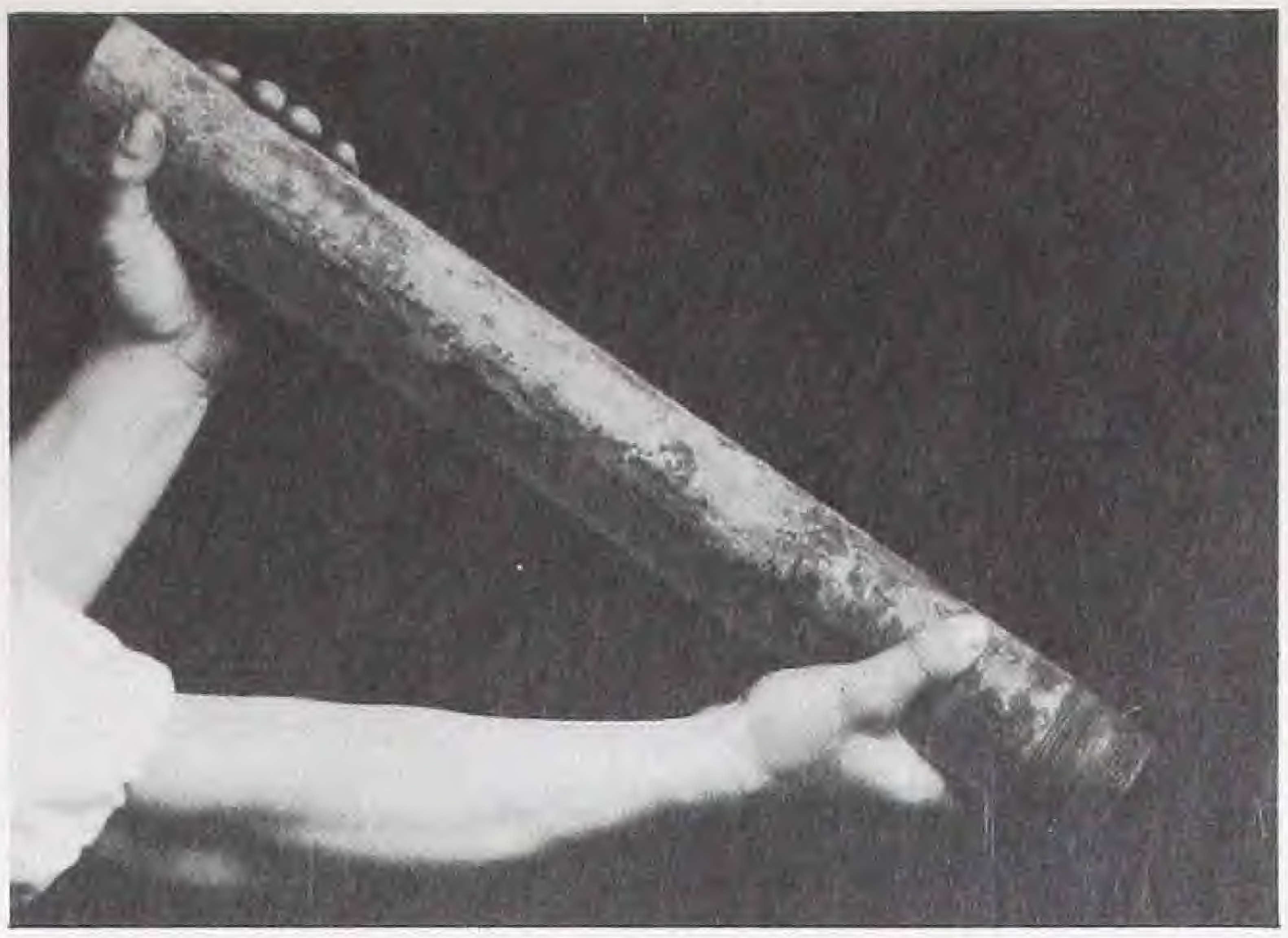

Fig. 23

Fig. 24

In Arkansas, an interesting comparative service record was obtained from one of the large oil companies.

Seamless steel tubing was used in a new well, and at the end of 15½ months, corrosion had caused so much deterioration that the tubing was scrapped. On nine occasions it had been necessary to pull the tubing.

Galvanized wrought iron tubing was then installed, and it remained in service for twelve months, at the end of which time the

well was abandoned. The wrought iron tubing was moved to another equally corrosive well where it gave over two years additional service. The transfer was made on the basis of 30% deterioration in the first well, and of course the tubing was carefully inspected before this figure was chosen. On only three occasions had it been necessary to pull the tubing for normal well repair work, and none of these repairs were necessitated by corrosion, or mechanical failure of the tubing.

The steel tubing originally cost \$660.00 and at the end of 15½ months its scrap value was considered negligible. The nine removal jobs cost \$40.00 each, making the total cost \$1,020 or \$65.80 per month.

The wrought iron tubing, plus three removal charges, less 70% credit, cost only \$442.00 or \$36.83 per month.

The well in which the tubing strings were run is shown in Figure 25.

The well shown in Fig. 26, was drilled near Chicora, Pennsylvania, at the time of the first "oil excitement" in that territory. After producing oil from the "third sand" for several years; it was drilled to the "fourth sand" from which it produced both oil and gas. Finally, after 53 years, the casing was pulled, the well was cleaned, and drilling was continued to a "speachley" sand from which over 200,000 cubic feet of gas were produced daily. The old casing was still in such good condition that it was returned to service in the same well. As might be assumed from its age, the casing was wrought iron.

Near Zollarsville, Washington County, Pennsylvania, a gas well came in at 2,783 feet with an open flow of 13,000,000 cubic feet per hour, and with a rock pressure of 850 pounds. The well was piped with 4" wrought iron tubing.

Recently, after 40 years service, the tubing was removed for cleaning. It was found to be in such good condition that it was run back into the well without even re-threading. The excellent condition of the material is evident from Fig. 27.

Fig. 25

Fig. 26

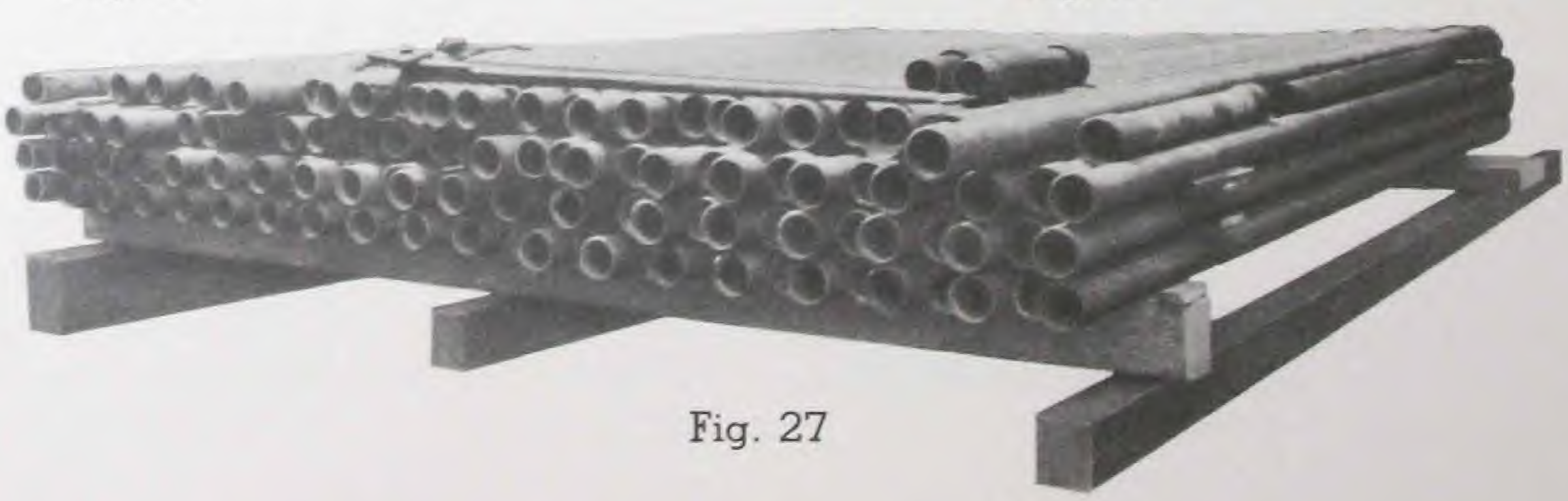

Fig. 27

GAS LINES

Wrought iron pipe is being widely used today for gas lines, and its ability to withstand soil corrosion is a major reason for its selection by engineers. Wrought iron lines can, therefore, be operated at high pressures for many years with a minimum of service interruptions. For gas service lines from mains to buildings, wrought iron has been found particularly suitable.

Louisville Gas and Electric Company, Louisville, Kentucky, has been using black wrought iron for service lines, and other users include Bridgeport Gas and Light Company, Bridgeport, Connecticut; Brooklyn Union Gas Company, Brooklyn, New York; Jersey Central Power and Light Company, Asbury Park, and Ocean City, New Jersey; Brooklyn Borough Gas Company, Brooklyn, New York; Missouri Power & Light Company, St. Louis, Missouri; Boston Consolidated Gas Company, Boston, Massachusetts; Montana Dakota Utilities, Minneapolis, Minnesota; and the Duluth, Minnesota Municipal Gas System. Honolulu Gas Company, in Hawaii has often used wrought iron for high pressure service lines, and only space limitations necessitate omission of the names of many more companies whose specifications call for wrought iron.

Experience forms a sound basis for wrought iron's selection for gas lines, and the life of a 16" line owned by the Pittsburgh and West Virginia Gas Company is typical. This line runs from Central to Littleton, West Virginia, a distance of about 30 miles. It was laid in 1895, and was not disturbed until 1932. At that time new couplings were installed instead of an out-moded type that had begun to develop leaks. The pipe was re-laid in the same trench. In 1933, it was struck by lightning, and this freak accident was described in the May 13, 1933, issue of Gas Age Record magazine. The break was quickly repaired, and the line is still considered by the owners as one of the most reliable in their network.

The 8" wrought iron gas line which runs from Bradenburg to Louisville, Ky., has had an interesting history. It originally extended from West Point, Kentucky, to Louisville, Kentucky, and was fifty years old when relocated. Fig. 28 shows the old pipe as it was taken from the trench and Fig. 29 shows it being welded together again prior to relaying. The excellent condition of the pipe is apparent, and no leaks could be found.

Fig. 28

Fig. 29

When the wrought iron line was 26 years old, it was paralleled by a steel line, in order to obtain increased carrying capacity. The steel has already failed, and has been replaced, after having been in service less than half the number of years the wrought iron was buried in the same location.

Gas Service Co., of Kansas City, Mo., conducted a 12 year test on 38 pipe samples exposed to soil corrosion. The samples were each ten feet long, and 35 of them were steel, covered with a wide variety of non-metallic coatings. In addition, there was a piece of uncoated wrought iron, a piece of uncoated steel, and a galvanized wrought iron specimen.

After only 4 years, all but three of the coatings had deteriorated to such an extent that they were useless. One of the three remaining coatings was affected by heat and soil pressure, and much of it had run to the bottom of the pipe. The other two were wrapped coatings, and while they still were of some protective value, moisture had penetrated them and serious rusting of the metal had occurred. The uncoated steel showed many deep pits, and the corrosion products were loose and flaky. The bare wrought iron showed shallow pitting well distributed, and tightly adherent corrosion products. The galvanized wrought iron was in perfect condition.

Subsequent inspections led to the conclusion that galvanizing was the only one of the pipe coatings tested that was satisfactory. Of the uncoated samples, the wrought iron showed markedly superior resistance to pitting.

A 12" wrought iron gas main runs from Camden to Trenton, New Jersey, and a 12" steel main continues on from Trenton to New Brunswick, New Jersey. In thirty-seven years, only one repair due to corrosion has been required on the wrought iron section. It occurred under a trolley line near Burlington, New Jersey, and was directly traceable to electrolysis. By the time the 26-mile-long steel line was 29 years old, at least one mile of pipe had been replaced as a result of corrosion.

In Moorestown, New Jersey, one of the first so-called "high pressure" gas lines (15#) was laid along Chester Avenue. Three-inch wrought iron pipe was used without any coating. When the Camden-Trenton main was laid the Moorestown line was connected to it. After 29 years, need for increased capacity made it necessary to parallel the old line with 6" pipe, and coated steel was used. The steel had been in only about 15 years when leaks began killing trees, and Fig. 30 shows the 44-year-old 3" wrought iron (right) and the 15-year-old 6" steel pipe at that time. The wrought iron was wire-

Fig. 30

brushed for a distance of 1000 ft., and no pits as large as $\frac{1}{8}$ inch in diameter could be found. Pits in the steel in the same trench can easily be seen in the photograph. One thousand feet of steel pipe were replaced, while the wrought iron remained in service.

Near one of the highways crossing the border between Allegheny and Armstrong Counties, in Western Pennsylvania, a $3\frac{1}{2}$ mile feeder line of 8″ 25# wrought iron pipe gave 38 years service operating at 60 pounds pressure. Construction work on the road finally made it necessary to dig up the pipe, and by re-routing the gas, the line was eliminated.

The old pipe was all in excellent condition when placed in stock, and the complete absence of any clamps or patches indicated that no repairs had ever been necessary. The pipe is shown in Fig. 31 shortly before it was re-installed in another location as part of a line operating at 100 pounds pressure.

Equitable Gas Company, of Pittsburgh, Pennsylvania, still has in service a line of 16″ O.D. $\frac{3}{8}$″ wall wrought iron pipe installed in the 1890's. It runs from Brentwood to Belle Vernon, Pennsylvania, and has, according to one of the company officials, given very satisfactory service.

At Atlantic City, New Jersey, the soil consists largely of beach sand soaked with fresh surface water. Hundreds of gas service lines, composed of black wrought iron pipe, have been installed for over 30 years and have given no trouble. Steel pipe, tried on several occasions was found to be unsatisfactory under the same conditions. An 8″ wrought iron gas main under Arctic Avenue from Stanton Avenue to Boston Avenue, began to leak after only seven years' service. When it was dug up for repairs, it was found that the cast iron fittings had graphitized. The fittings were replaced and the pipe was put back in service. After about 30 years' service, the pipe was still in use and no further trouble had been experienced.

We have been informed by the Superintendent of Distribution, of the Jersey Central Power and Light Company at Asbury Park, New Jersey, that some of the gas mains in the western part of Asbury Park have been in service for over 70 years. In this distribution system wrought iron is also being used extensively for salt water river crossings in the southern part of New Jersey where the life of steel was found to be less than one decade.

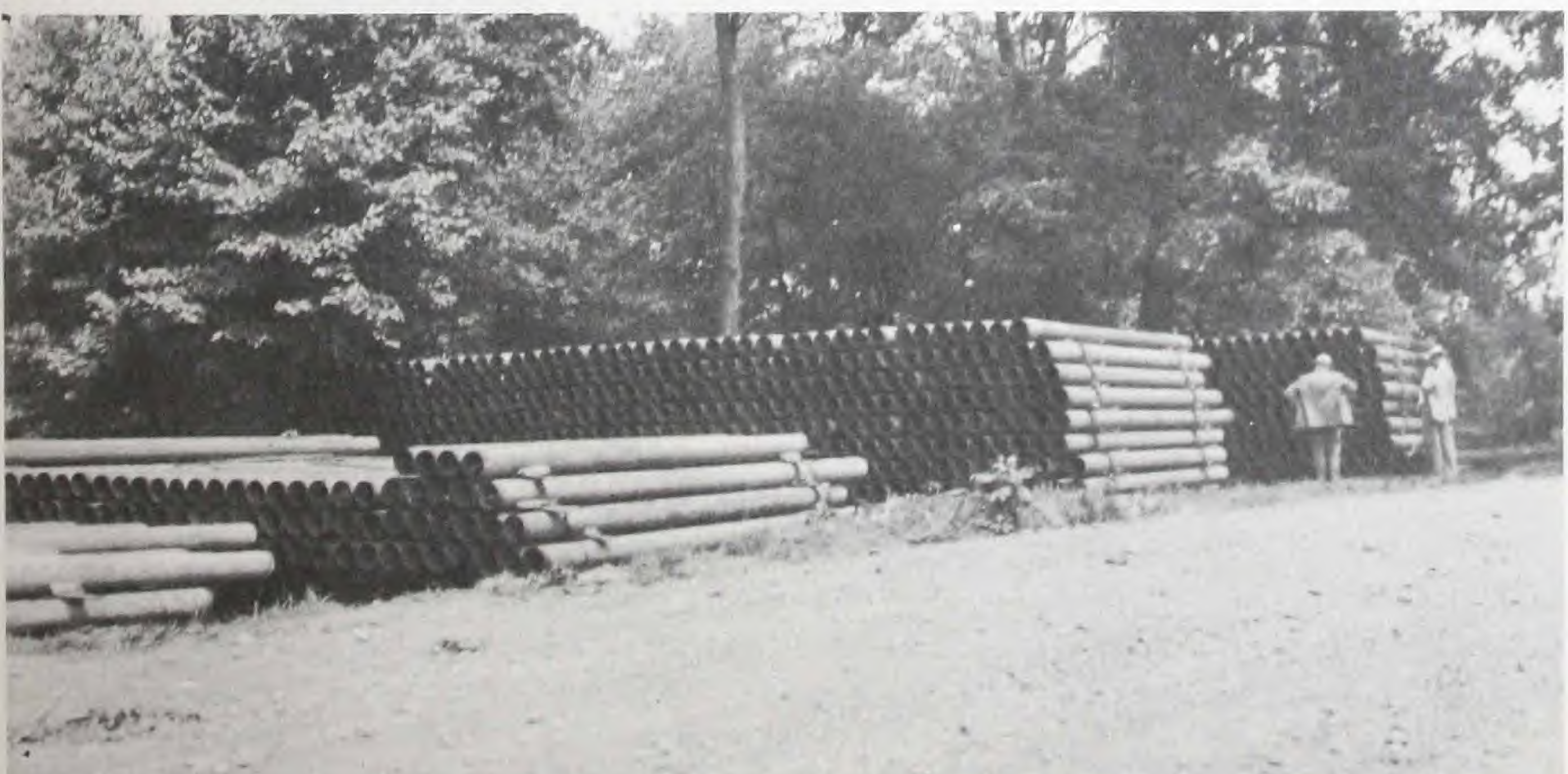

Fig. 31

OIL LINES

If the designer of the famous "One Hoss Shay" that ran until one day it fell completely apart, all at once, had been in charge of laying oil lines, he undoubtedly would have tried to achieve a "balanced" installation. In other words, it is an accepted fact that in every long oil line there are "hot spots" where corrosive action is unusually severe. Corrosion-resisting pipe should always be used for these stretches in order to achieve maximum service before the first failure occurs.

Wrought iron has been used for river crossings and other corrosive sections of many lines, as well as for long runs, when the ultimate in service life is desired.

Service records describing a few typical lines clearly indicate the superiority of wrought iron for cross-country lines, as well as for other underground oil piping.

Fig. 32 shows two lines of 6" wrought iron pipe, with welded joints, being installed near Houston, Texas. They cross the Houston Ship Channel and lie in a trench eleven feet deep dredged in the bottom of the channel. Galveston Bay, an arm of the Gulf of Mexico, lies adjacent to the body of water shown in the photograph, and so the pipe is exposed to the corrosive action of soil saturated with sea water.[11]

Fig. 32

[11]Corrosion resulting from sea water is discussed in the bulletin "Wrought Iron in Salt Water Service". Copies will be furnished gladly on request.

Two steel lines, formerly used, failed after 8 and 10 years service, respectively, and were removed. The wrought iron lines have been in service over nine years, and according to the Division Superintendent in charge, they have never given any trouble at all.

The main oil lines formerly operated by the U. S. Pipe Line Company were 4" and 5" wrought iron, and extended from the oil fields in the northwestern part of Pennsylvania diagonally across the state to Marcus Hook, near Philadelphia. These lines were laid between 1893 and 1902. Fourteen river crossings and twenty-six electric railway crossings were necessary in laying the pipe. The average operating pressure was 1000 psi.

The company disbanded in 1925 and a major portion of the pipe was dug up, cleaned, and sold for re-use. The average age of the pipe, when removed, was about 30 years, and the General Superintendent of the company has written us that the pipe was ". . . . . . in excellent condition. Some of the material was pitted, but the pits were shallow and well distributed. There was practically no deep pitting."

One large oil company purchased many miles of the old lines. Some sections were left in the ground and continued in operation, while others were transferred to Oklahoma. There, a 44-mile run of 4" wrought iron was laid, including a crossing of the North Canadian River. The wrought iron was then thirty-one years old. Two years later, some 11-year-old 4" steel pipe was used to parallel the eastern 22-mile section of the wrought iron line. After nine years more use, when the wrought iron was forty-one years old, and the steel was twenty years old, the steel river crossing was replaced with new wrought iron. At the same time, we were told by one of the company officials that the western end of the same wrought iron line was in better condition than some new steel pipe which had been used to parallel it only

seven years earlier. Eventually, when the pipe was forty-five years old, the wrought iron line was replaced, but it still brought 25 cents a foot in the used pipe market and was resold for other services.

Another oil company purchased some of the U. S. Pipe Line Company's wrought iron pipe and used eight and one-half miles of it, plus thirty-five miles of new steel pipe, to lay a line in Louisiana. After fourteen years' service, the steel was giving more trouble than the 46-year-old wrought iron. The same company used some of the wrought iron for a line in Texas and it remained in service about thirteen years. When removed, over half of the 43-year-old wrought iron could be reconditioned and used again elsewhere.

Various operators in the Ohio-Pennsylvania fields purchased sections of the old lines, either in the ground or after removal. One such section was used until a few years ago, in its original location and, when removed, it was in such good condition that over 90% of it was relaid.

The coastal plain country a few miles north of the Gulf of Mexico in the neighborhood of Galveston Bay is largely made up of sour soil, and trouble due to pitting is often experienced with pipe lines.

It is in this region that one of the pipe line companies, whose name we have been asked to withhold, laid a line of 6" uncoated wrought iron pipe, twenty miles long. The maximum working pressure was 750#, and the minimum, 250#.

After twenty-four years of practically trouble-free service, the line was removed and re-conditioned. Only 2300 feet (2.2% of the total) were set aside as questionable. The rest of the pipe was returned to stock for future use.

At the same time, a typical length was sent to the pipe line company's own metallurgical laboratory for examination. The following quotation is from their laboratory's report.

"Fig. 2, (See Fig. 33 of this bulletin) showing a pit magnified four times, illustrates that after corrosion proceeded to a certain depth at which slag stringers were reached the corrosion concentrated on these stringers and the pits did not get any deeper. Once pits form in steel pipe the corrosion is likely to make these pits deeper without attacking the rest of the pipe. More even corrosion of the metal partly accounts for the longer life of the wrought iron as compared with steel pipe."

Fig. 33

Fig. 34

Farther on in the same report, a photograph reproduced as Fig. 34 was included. It shows the broad, shallow, over-all type of corrosion typical of that which forms on genuine wrought iron under most conditions of soil exposure.

As a result of this and other similar experiences, the same company has used wrought iron in more recent years for "hot spots" and river crossings in Texas, where they have had unsatisfactory service from steel.

A direct comparison between the corrosion resistance of uncoated wrought iron and coated steel pipe is provided by the history of two oil lines installed near Sabine Lake, an arm of the Gulf of Mexico about 70 miles east of Galveston, Texas.

For a distance of nearly 3 miles these two lines were buried at the same depth, and only a few feet apart. The wrought iron was 10″ 45# pipe, and the steel was 10″ 40# pipe. Three different soil conditions were encountered, and for this reason the story of the lines may best be divided into three parts.

(a) The first soil encountered was a semi-marsh of heavy muck or clay, with poor drainage and acidic conditions. For nearly half of the year, salt water floods the area. The steel was coated with primer and paint when laid, but when it was inspected after only four years, twenty-seven saddles were found over rust holes which had developed in the 1000 feet of pipe in this zone. After eight years, under identical conditions, no holes had appeared in the uncoated wrought iron pipe.

(b) Before laying the next 14,000 feet section, a levee was built along the right of way to raise the lines about two feet above a salt marsh. At some places the lines were completely exposed, while at others they were buried to a depth of 6 inches in the levee. Measurements at 23 bell holes in this zone revealed that after eight years, the average pit depth in the primed and painted steel was about $\frac{1}{16}$ inch, while in the bare wrought iron the pits averaged only 72% as deep. The contrast between the localized pitting on the steel and the broad shallow corrosion pattern on the wrought iron was noticeable.

(c) In the third section, both lines passed under a salt water inlet for about 300 feet. Corrosion was very severe in this region, particularly near the shore where the pipe is buried in the earth. After eight years, the wrought iron was still in service and no failures had occurred. Very few pits were found, and the deepest was $\frac{3}{32}$ inch. The steel, which had, of course, originally been coated, was so badly pitted that it was completely replaced with wrought iron.

For the entire line, the average pit in the steel was 2.1 times as deep as in the wrought iron.

The inspecting engineer also concluded that "The use of a paint on the steel ten-inch line made it easier to clean, but did not decrease the rate of corrosion of the pipe."

One of the pipe line companies in the Eastern U. S. has, for over half a century been operating a line of 6″ wrought iron pipe about 120 miles long. When the wrought iron line was 30 years old, a parallel line of 6″ steel pipe was laid. Fig. 35 shows the two lines when a section was re-located several years ago.

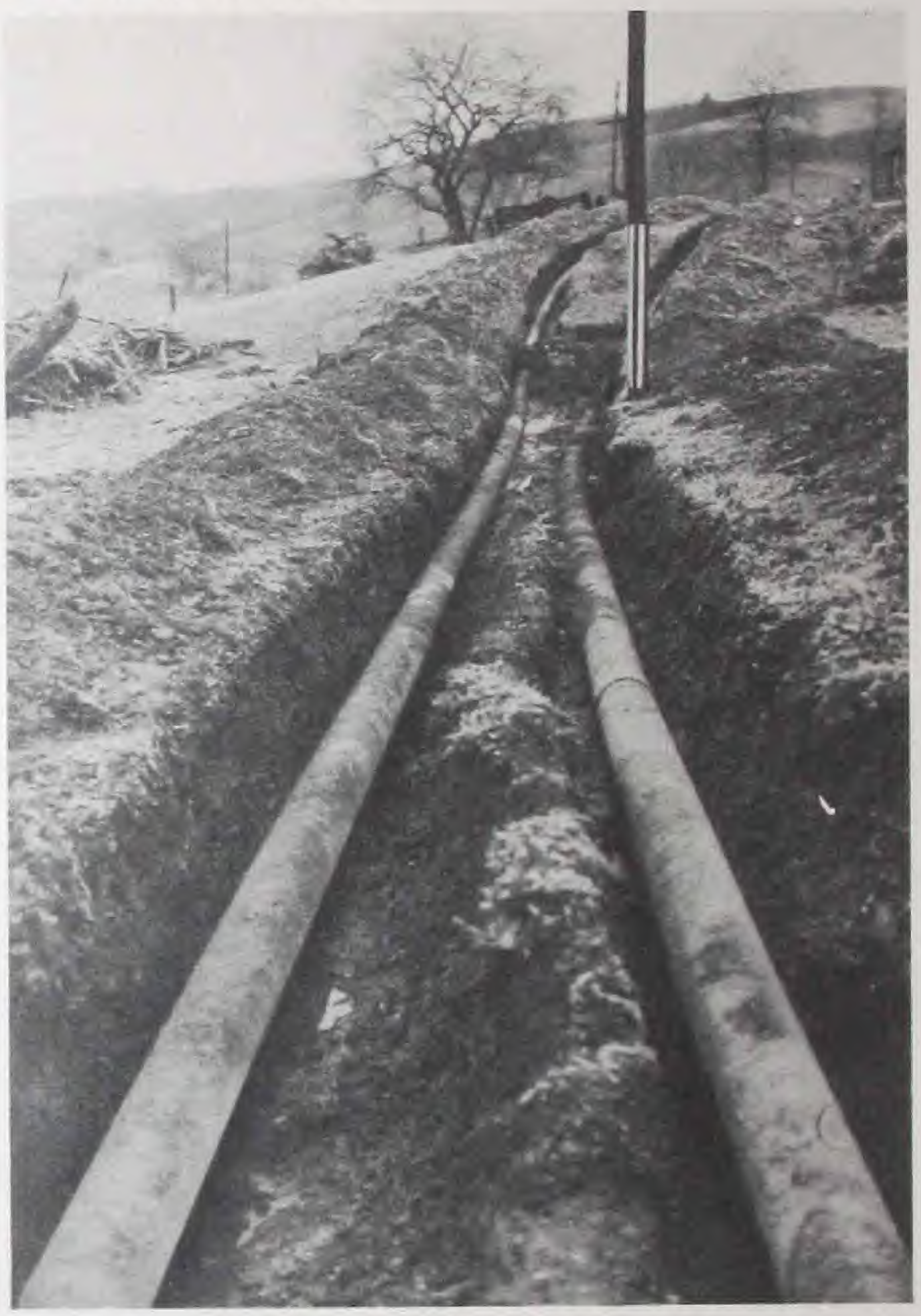

Fig. 35

Records of leaks in these two lines provide an excellent indication of the superiority of wrought iron over steel under identical conditions. In the 24 year period following the installation of the steel pipe, 45 leaks directly attributable to corrosion occurred. During the same 24 year period, the wrought iron developed only 28 leaks. Thus, while the wrought iron was over twice as old as the steel at the end of the test, only a little over

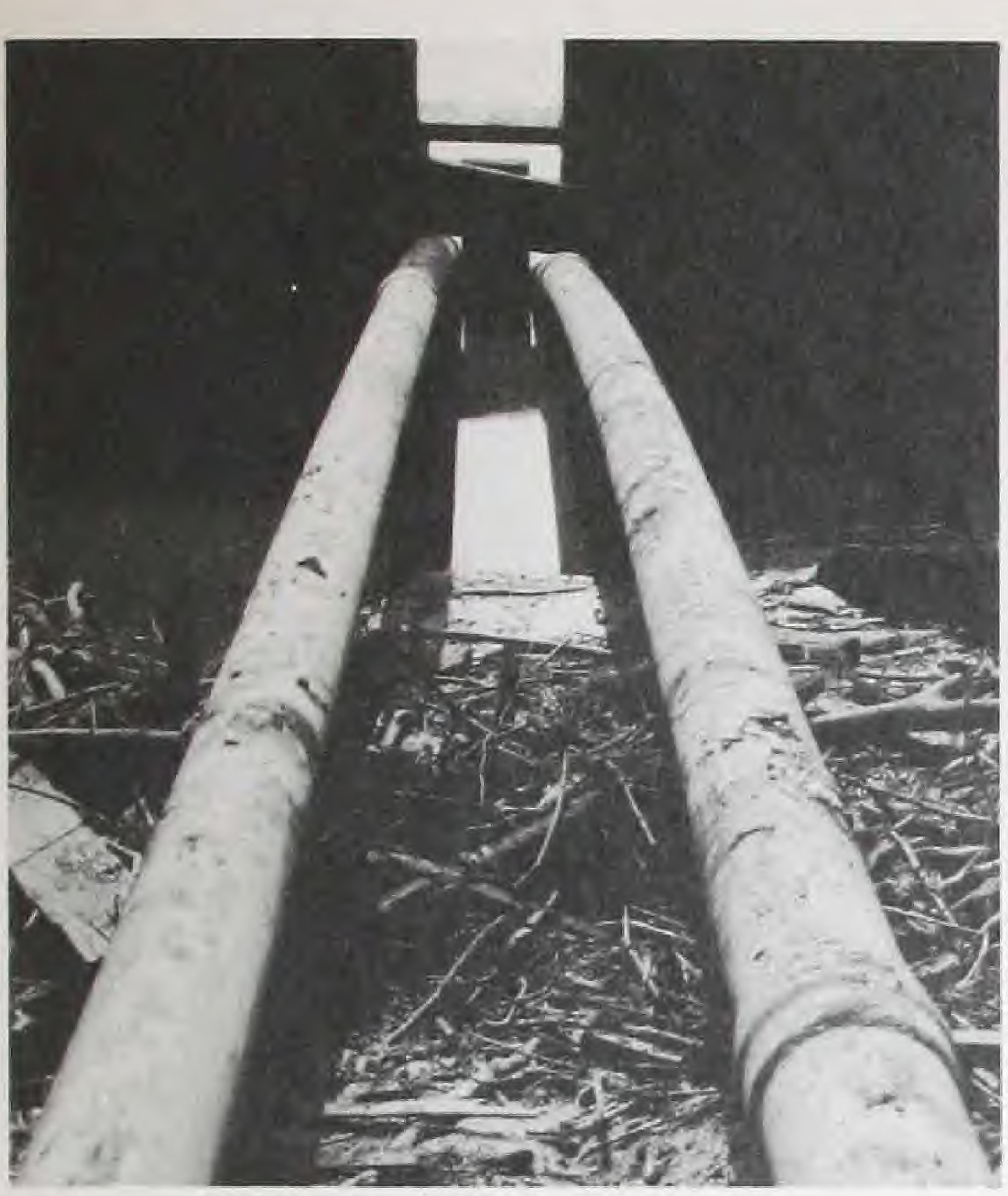

Fig. 36

Fig. 37

Fig. 38

Fig. 39

half as many pit holes occurred. During the last few years of the record period, the operating pressure of the steel line was reduced 50# per square inch below that carried in the wrought iron line, in order to avoid any further increase in the number of leaks.

Figs. 36 and 37 show two lines of 6″ Byers Wrought Iron pipe which carry crude oil under the Schuylkill River near Philadelphia to one of the large refineries. As is apparent from the photographs, the lines are of all-welded construction.

In the fall of 1938, Simonds Saw & Steel Company used wrought iron for 6″ oil supply lines to underground oil storage tanks, 2″ oil pressure lines from the underground storage tanks to smaller tanks inside the plant, and for air lines to these underground tanks. Other underground wrought iron services included water lines, steam supply lines, and steam returns. Fig. 38 shows 3 of the 6″ oil lines being installed.

With the increasing use of Diesel-powered trains, the need for fueling stations has arisen. One such station, at Danville, Virginia, is shown in Fig. 39. It is one of many similar stations on the Southern Railway Company's lines. All the fuel oil piping is 4″ black wrought iron pipe.

GASOLINE LINES

External corrosion of gasoline lines differs little, if any, from that encountered by underground oil lines, water lines, and other underground lines. For this reason, only passing mention need be made of soil action on gasoline lines.

Localized internal corrosion has, however, often been observed and this is believed to be due to small amounts of water in the gasoline. While all the contributing factors are not clearly understood, it is thought that the water becomes highly corrosive by dissolving impurities present, in small quantities, in the gasoline.

For gasoline lines, it is suggested that scale-free (pickled) black wrought iron pipe be used. Galvanized wrought iron has also been successfully used but some recently-received evidence indicates that an uncoated interior surface is preferable. Pipe galvanized on the outside only is available for service where soil action is severe.

Wrought iron is widely used for underground gasoline lines and its resistance to corrosion, and particularly to pitting, fits it for this service to an unusual degree.

For example, wrought iron underground gasoline lines are in service at the Allegheny County Airport, near Pittsburgh. After eight years' use, we were informed that the lines had never required any repairs. Also, at Baltimore, Maryland, 1″ to 3″ wrought iron pipe is used for underground gasoline lines at the Municipal Airport, and the gasoline lines at a number of the newly-constructed army air bases are wrought iron.

At one of the large aircraft plants in central Connecticut, 2½″ and 3″ extra strong wrought iron pipe was used for underground gasoline lines.

The New York, New Haven & Hartford Railroad installed wrought iron pipe at their station in Hartford, Connecticut, as part of the underground distribution system for filling stations to supply the motor busses they operate.

At La Libertad, Equador, South America, there is a submarine gasoline line of 10″ black wrought iron pipe approximately two miles long. The material was pickled, washed, and the remaining acid was neutralized in an alkali wash before the pipe was shipped.

Space limitations prohibit a complete description of the many other wrought iron gasoline line installations of which we have records, but it is hoped that when special problems arise, an opportunity will be granted us to present additional data.

TANKS

The same corrosion-resisting metal from which wrought iron pipe is made is available in the form of plates suitable for tank construction.[12] Easily fabricated, these plates have been used for a large number of tanks and a few of the underground installations are mentioned here. It is suggested that whenever soil conditions are severe, or internal corrosive action is anticipated, that serious thought be given the use of wrought iron. By using the same material for both the tank and its connecting pipe lines, uniform resistance to corrosion is assured.

Wrought iron was recently selected by the U. S. Engineers for thirty-three underground gasoline storage tanks. The plates required were ⅜″ thick and all joints were welded. Fig. 40 shows several partly-completed units in the fabricating plant.

At Eastern States Milling Company's Plant in Buffalo, New York, two underground fuel oil tanks, 8′ in diameter, and 32′ long, were

[12] In the bulletin "Wrought Iron for Tank Construction" wrought iron applications are discussed in considerable detail and copies will be furnished gladly upon request.

recently installed. They are shown in Fig. 41 and were fabricated from 3/8" genuine wrought iron plates by Oldman Boiler Works, Inc., in Buffalo. The method of fabrication of the heads can be seen in Fig. 42.

Fig. 43 shows a 25,000 gallon genuine wrought iron tank, used to store number six grade fuel oil, or Bunker "C" fuel oil, at a large industrial plant. As can be seen by the proximity of the railroad track, vibration, as well as corrosion, undoubtedly contributes to the severity of the operating conditions.

At one of the Navy Yards, the ground is so low that whenever an excavation more than a few feet deep is made, sea water seepage becomes troublesome. To overcome this difficulty, 1/4" welded wrought iron shells or open-top tanks have been built, completely lining the excavations. Then concrete walls and bottoms have been placed inside the tanks, and on several occasions, an inner liner of wrought iron has also been used. Thus, in gun annealing pits, and elevator pits, there are two wrought iron shells, separated by about a foot of concrete. The concrete provides sufficient weight to keep the whole assembly from floating, as the sea water seeps into the excavation. Sand blasting pits and propellor test pits have been lined in a similar manner.

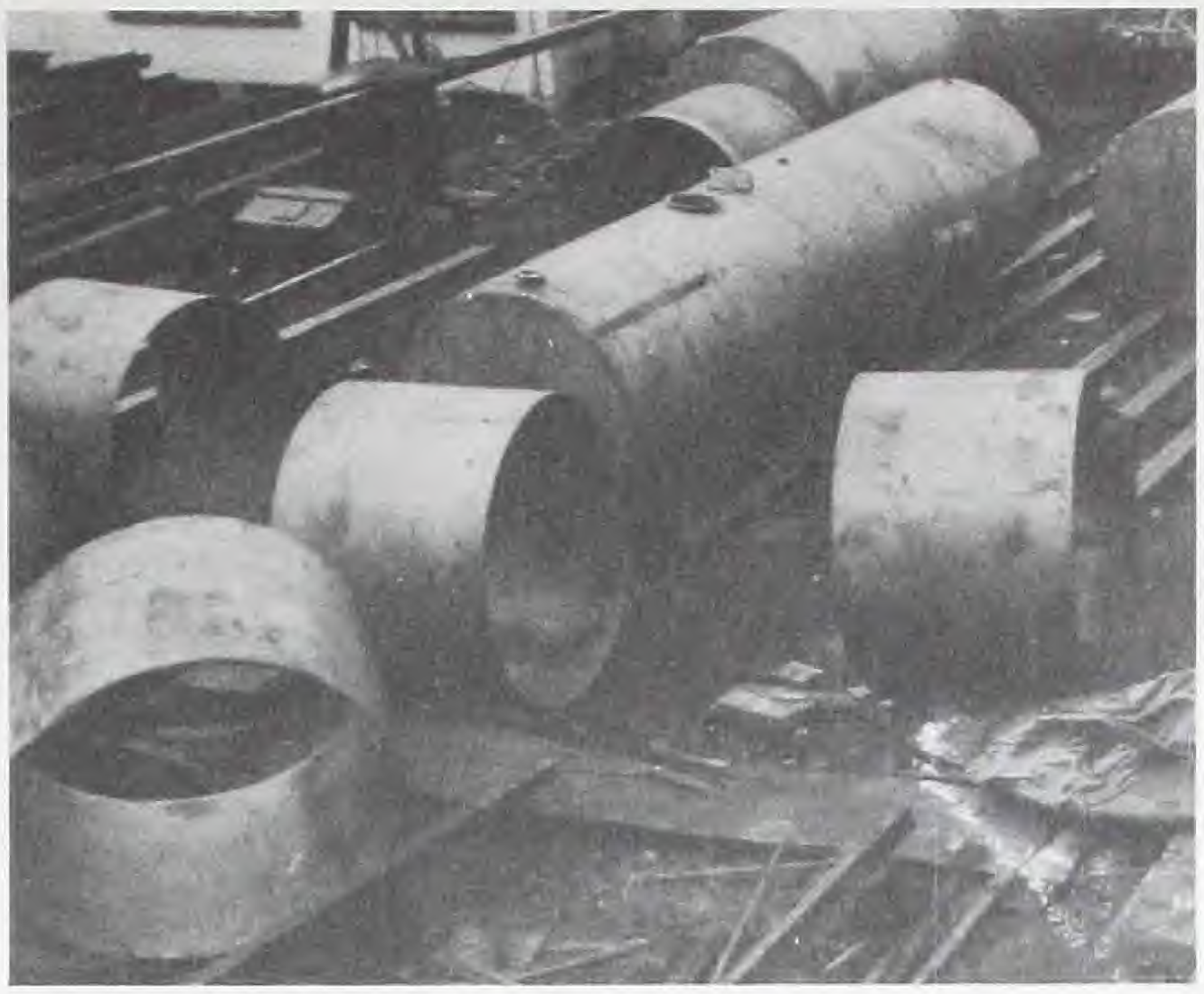

Fig. 40

Fig. 41

Fig. 42

Fig. 43

STEAM DISTRIBUTION SYSTEM PIPING

When condensate, hot water, or steam lines must be run underground, it is customary to insulate them. Often a concrete or tile duct is constructed and the pipe is supported in this duct so that there is an air space on all sides. Loose insulating material may also be packed into the air space, or pre-formed insulation may be fastened around the pipe.

At first, it might be assumed that the heat of the pipes would dry the duct and insulation, creating relatively non-corrosive conditions. In some cases this is true, but in many others it is not.

When steam lines are used for heating only, the ducts are cold throughout a major portion of the year, and it is practically impossible to keep moisture from accumulating in such a conduit. Many of the sectional conduits do not even approach water-proof construction. Once ground water enters the duct, and a film of water forms on the pipe, atmospheric gases dissolve in the water, and active corrosion follows.

When heat is again applied, a hot, humid atmosphere favorable to scaling is created. Large flakes of rust often form, and unless corrosion resisting pipe is used, failures may be a serious problem.

It is recommended, therefore, that ducts be placed on a broken rock or gravel fill, so that adequate drainage is provided. The duct itself should be as water-tight as possible, and provisions should be made for ventilating it when heat is not applied. Leaving the vents open during the early part of the heating season will also help to allow moisture to escape. Insulation should be free of corrosion-promoting sulfur compounds, and cinders should be avoided in the back fill. Finally, corrosion resisting pipe should always be used.

Records of some recent installations as well as some which have given many years' service have been assembled, and it is believed that they illustrate wrought iron's suitability for underground heating lines.

In the underground steam distribution system in Champaign, Illinois, one of the steam lines installed soon after the turn of the century was 10" wrought iron pipe. It was insulated with a 4" casing of kiln-dried wood, lined with asbestos and tin. After 39 years' continuous service, the line was still operating and had required no maintenance whatsoever.

A few years later, in the same system, a 16" wrought iron steam line 2200 feet long was installed, with similar insulation to that used on the 10" line. After 13 years' use, the line was moved to another location, and the pipe was, of course inspected before relaying. It was all in good condition with the exception of a single length which was badly corroded. Analysis revealed that the corroded length was steel; the rest of the line was wrought iron. The piece of steel was replaced, and the rest of the line was still operating when checked, recently, after 29 years' service. No further maintenance had been required.

Since the middle 1920's, when the residential village of Mariemont, near Cincinnati, Ohio, was constructed by the Thomas J. Emory Memorial, a central steam distribution system has been in service. Fig. 44 shows one of the steam mains being welded, prior to application of insulation consisting of two layers of asbestos, one of bright tin, and several inches of wood. Tar-paper was placed over the insulated pipe before the trench was back-filled. The insulated main, ready for the backfill, is shown in Fig. 45.

Wrought iron was used for all the steam lines, and about 3½ miles of mains were installed. At their extremities, the mains are over a mile from the power house. No condensate returns were installed.

During a recent check, fourteen years after the original installation, the chief engineer stated that the underground steam lines were "still in perfect condition."

Welding was the method selected for joining the lengths of wrought iron pipe shown in Fig. 46. This photograph was taken at Phillips Academy, Andover, Massachusetts, and shows part of the underground steam heating system being installed.

Similar installation methods have been used at Dartmouth College, Hanover, New Hampshire, ever since wrought iron was used in the original central heating system. The photograph marked Fig. 47 was taken in 1897 and shows workmen dumping a mixture of ground cork and sawdust around the pipe as it lay in its tile duct.

Practically all the original wrought iron pipe is still in use. Fig. 48 shows wrought iron pipe being installed in a recent addition to Dartmouth's steam system, when an asbestos-insulated line was run to the new Physics Building.

Fig. 46

Fig. 44

Fig. 45

Fig. 47

Fig. 48

In sewage treatment plants, wrought iron is often used for underground heating lines, and Fig. 49 shows 4" galvanized wrought iron pipe being installed in split tile conduit to carry hot water used for heating sludge digestion tanks at the Springfield, Massachusetts, Sewage Treatment Plant.[13]

An interesting method for handling 6" and 14" wrought iron pipe was recently used to facilitate installing some low-pressure steam lines at Iowa State College, Ames, Iowa. Fig. 50 shows part of the pipe being placed in the concrete box tunnel. The joints were all welded.

At the St. Bernard Parish Court House and Jail, Arabi, Louisiana, wrought iron was used for all tunnel piping. Part of the installation is shown in Fig. 51 shortly before the tunnel was covered.

The State of Rhode Island Bureau of Hospitals has used large quantities of standard weight black wrought iron pipe for steam and condensate lines in concrete ducts. Fig. 52, shows (L. to R.), a medium pressure steam line, a high pressure steam line and a condensate line, being installed in a concrete duct at the State Infirmary, Wallum Lake, Rhode Island. All three lines are welded, and were insulated before the duct was covered and the earth replaced.

Nearly 200 tons of wrought iron pipe were used in a similar installation at the Rhode Island State Hospital and Infirmary at Howard, Rhode Island. This insulated pipe is shown in Fig. 53.

[13]For more detailed information on other uses for wrought iron in similar plants, write for a complimentary copy of our bulletin "Wrought Iron for Sewage Treatment and Disposal Installations".

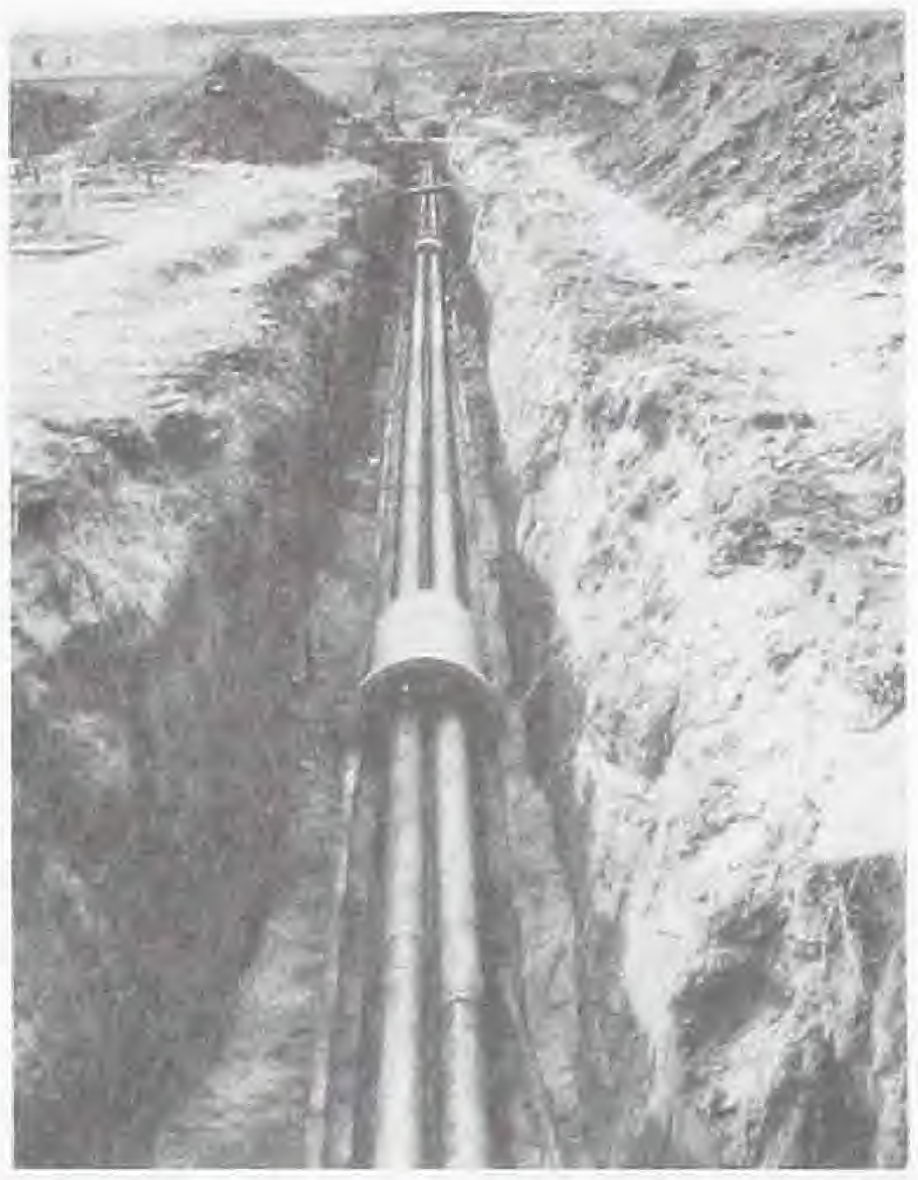

Fig. 49

Fig. 50

Fig. 53

Fig. 51

Fig. 52

ELECTRIC CABLE CONDUIT

Wrought iron has been selected for many underground conduit installations where interruptions of service would be costly, or difficulties would be experienced in making replacements.[14] River crossings, where the conduits are buried in a trench dredged in the river bottom fall in this class, and lines buried under paved streets are another popular application. It is often used on bridges and piers to resist corrosion and vibration. While the use of wrought iron conduit on a broad scale is a fairly recent development, there are a number of installations which have been in service for a considerable period of years.

The cable conduit shown in Fig. 54 was installed to carry the cables of the American Telephone and Telegraph Company and the Illinois Bell Telephone Company under the Calumet River, near Chicago. Over three miles of 3½" black genuine wrought iron pipe were required, and the lengths were joined with threaded couplings. Fillet welds were then made at each end of each coupling to reinforce the joints and provide a perfectly tight seal. After being lowered into place, the lines were filled with a light mineral oil which prevents condensation and serves to indicate that there are no leaks. The conduit has been in service over 13 years, and a recent inspection revealed that it is still functioning perfectly and that no loss of oil has occurred.

Some of the underground conduits owned and operated by the United Illuminating Company in and near New Haven, Conn., have been in service over a third of a century and are still in good condition. No protective coating was used. Recently a cable crossing under the Housatonic River was installed, and wrought iron was selected for the 5" underground conduit leading from manholes on each side of the river to the river banks. Wrought iron was used for a submarine cable conduit under the Hop River, near Willimantic, Conn., and other installations of wrought iron conduit by the same company include run-out leads to service poles, and a variety of underground power line installations.

The County of Essex, New Jersey, uses 2" galvanized wrought iron cable conduit in connection with their modern "vehicle detectors". These sensitive electro-magnetic

Fig. 54

Fig. 55

[14]Wrought iron cable conduit differs from wrought iron pipe supplied for other services in that extra care is taken to ream out all burrs, and a metal plug is passed through each piece of pipe to be sure there are no obstructions or rough spots. Wrought iron cable conduit is supplied either black or zinc coated (galvanized) in random lengths. It should not be confused with the steel conduit ordinarily used for raceways in buildings. A supplementary publication on wrought iron for cable conduit is available on request.

devices are actuated by the magnetic effect produced as a vehicle moves over them, and they are used to change signal lights where it is necessary to admit cars to main highways from side roads. When the car passes over the detector, the signal light changes, stopping traffic on the main artery for 20 seconds. Fig. 55 shows a unit being installed, and the conduit leading to the signal can be seen in the background.

Wrought iron pipe has the rigidity and toughness necessary to permit it to be jacked or driven through the hard-packed soil under roadways. The New Jersey State Highway Department has a standard specification calling for wrought iron for underground cable conduit, and Fig. 56 shows a typical installation being made. Only a short trench was dug at each end of the run of conduit. The intervening section was driven through from one end, using an air hammer.

It is often observed that when a pipe extends out of the ground, the most severe corrosive action occurs at or near ground level. Alternate wet and dry corrosive action is encountered. Frequently scaling can be observed, usually between the pipe and an adjacent pole, near ground level. Soil corrosion, accelerated by acids leached from the wood pole, is also a factor.

Chicopee Electric Light Company, Chicopee, Mass., has found that wrought iron lasts longer than other ferrous metals for this service, and one of their installations is shown in Fig. 57.

In 1880, what is believed to be the first underground electrical cable was constructed by two professors in the Department of Physics at Cornell University, Ithica, New York. They joined lengths of $\frac{3}{4}$ inch wrought iron pipe together, using Tees instead of couplings, and passed number 8 copper wire wrapped in muslin through the pipe. Melted paraffin was then poured into the open side-branches of the Tees until the pipe was full. This insulated the wire and protected it from moisture. The pipe was then buried in the ground between Morrell Hall and Sage Chapel, a distance of about 500 feet.

A test of the old cable was made over half a century after its installation, and it still was found to be in operating condition. A sample of the pipe was analyzed and the fact that it was wrought iron was confirmed.

The Harlem Ship Canal, sometimes referred to as Spuyten Duyvil, is the brackish and frequently turbulent body of water between the mainland and the Island of Manhattan which is, of course, the heart of New York City.

Fig. 56

About twelve years ago, the New York Central Railroad was faced with the problem of crossing this stream with the high tension lines to supply the West Side Improvement being constructed by the railroad. Fig. 58 shows the entire group of thirty-six 4" extra heavy wrought iron conduits being lowered into the 32 ft. deep channel. Recent conversations with engineers in the engineering and maintenance departments of the railroad revealed that the installation has been entirely satisfactory.

The Thomas A. Edison Memorial Bridge across The Raritan River connects Perth Amboy and South Amboy, New Jersey and is an important link in the highway system leading to the New Jersey shore resorts. Conduit on the bridge as well as the underground conduit on the approaches is all galvanized wrought iron. Nearly 3 miles of pipe were required. Some of this conduit, ready to be covered with soil, is shown in Fig. 59.

Signal cables paralleling the Pennsylvania Railroad Electrification near Newark, Delaware, are protected by wrought iron conduit where they pass under Christiana Creek. Floods had caused trouble before, so a trench was dug in the creek bed, four lines of 3" extra strong conduit were laid, and cement was poured over the lines. Fig. 60 shows this crossing being installed.

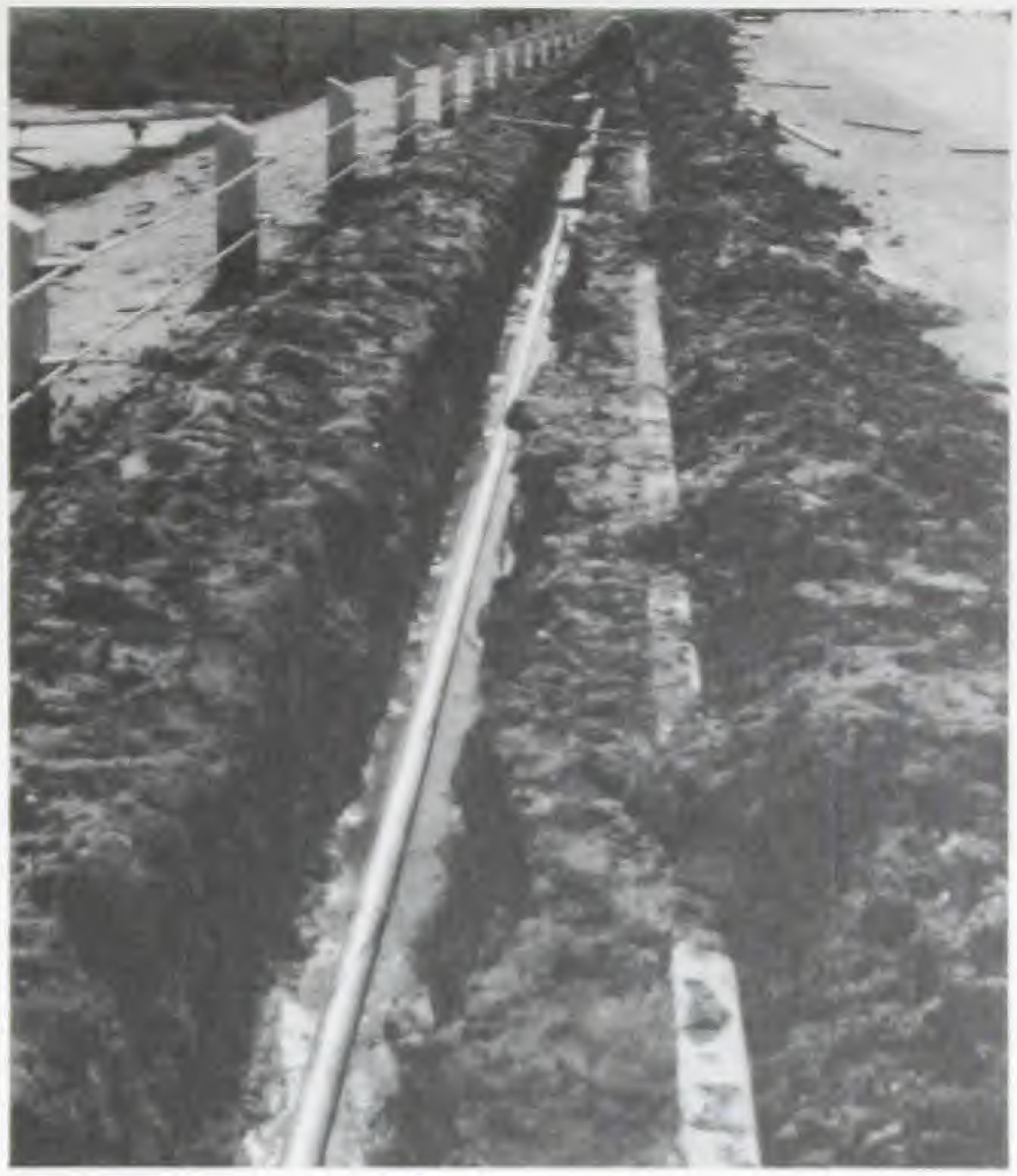

Fig. 59

Fig. 60

Fig. 57

Fig. 58

CONCLUSIONS

In the first part of this bulletin, some of the more important factors affecting soil corrosion are outlined, and some of the theoretical aspects of soil corrosion were noted. A study of the theory, as well as of test results, led, however, to the conclusion that predictions based only on test results or laboratory analyses are of doubtful value and should be used only after it has been demonstrated that they are in agreement with experience data obtained from full-scale projects. In other words, the position has been taken that test results by themselves have little real value and are useful only when correlated with actual experience data. For this reason, the principal emphasis in the remainder of the bulletin is on records of underground pipe lines which have been in use for many years.

Among the major wrought iron applications, water, oil, and gas lines have been treated in some detail. Sections have also been devoted to water wells and to oil and gas wells. Cable conduit, intended for use as protection for heavy electrical conductors, and underground tanks, steam lines, and gasoline lines are other topics to which attention has been given. In many cases, direct comparisons of the durability of two materials in the same service have been possible. These records are particularly useful as indications of the superiority of wrought iron for underground work.

In looking into the past, the intent has always been to learn something useful, which can be applied to future projects. Wrought iron pipe is being used today for more applications than ever before, and each new service involves a new set of corrosive conditions. Usually, however, somewhat similar exposure has been encountered before, and if the lessons of the past can be correlated and made available, solutions to new problems can be more easily found.

In each section of this bulletin, the old and the new have both been included, and each section deals with an application for which wrought iron has been proven suitable. It is hoped that these records will be useful to the engineering profession. Also, if at any time additional data might be useful, it is hoped that designers will have no hesitancy in writing to the Engineering Service Department, A. M. Byers Company, Pittsburgh, Pennsylvania.

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